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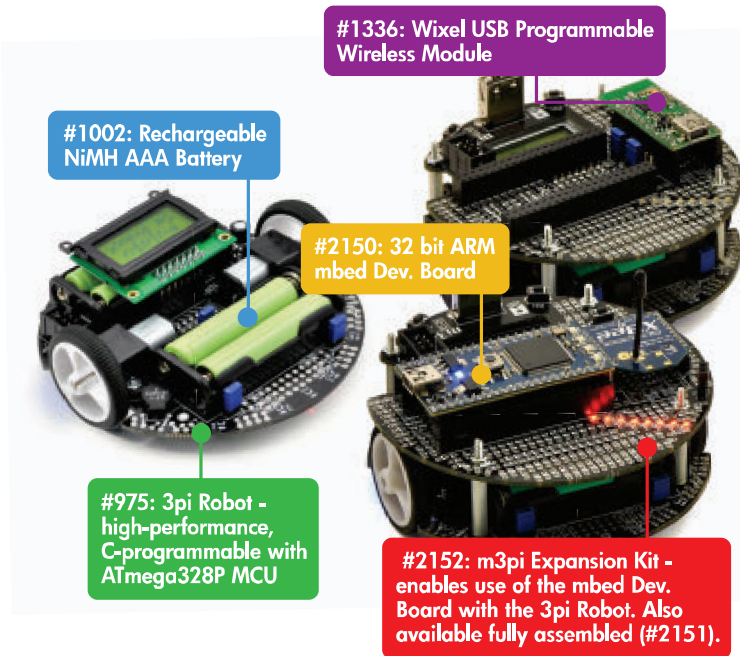
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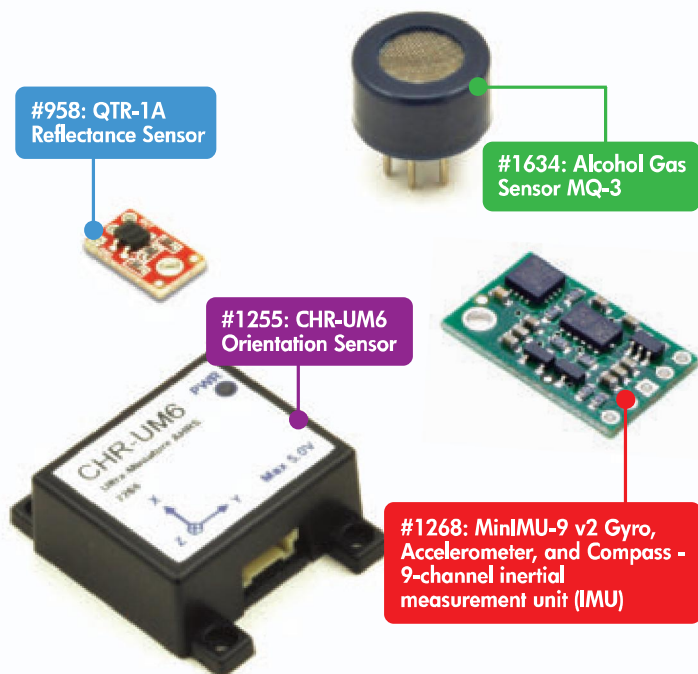
Robots and Robot Kits: Pololu 3pi and m3pi



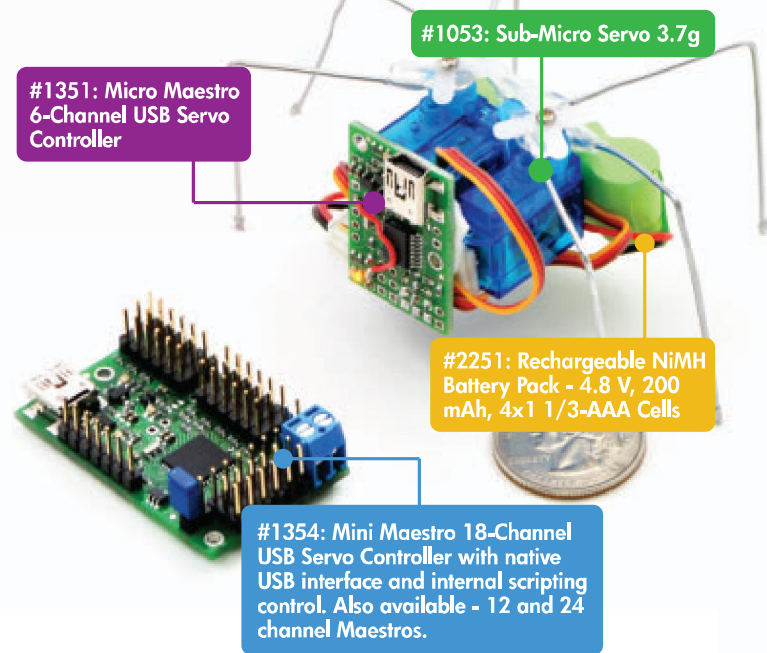
Programmable Controllers: Wixel and Wixel Shield



Sensors: Orientation, Reflectance and More



Hobby/RC Servo Controllers: Micro and Mini Maestros



Finding the right parts for your robot can be difficult, but you also don't want to spend all your time reinventing the wheel (or motor controller). That's where we come in: Pololu has the unique products - from actuators to wireless modules - that can help you take your robot from idea to reality.

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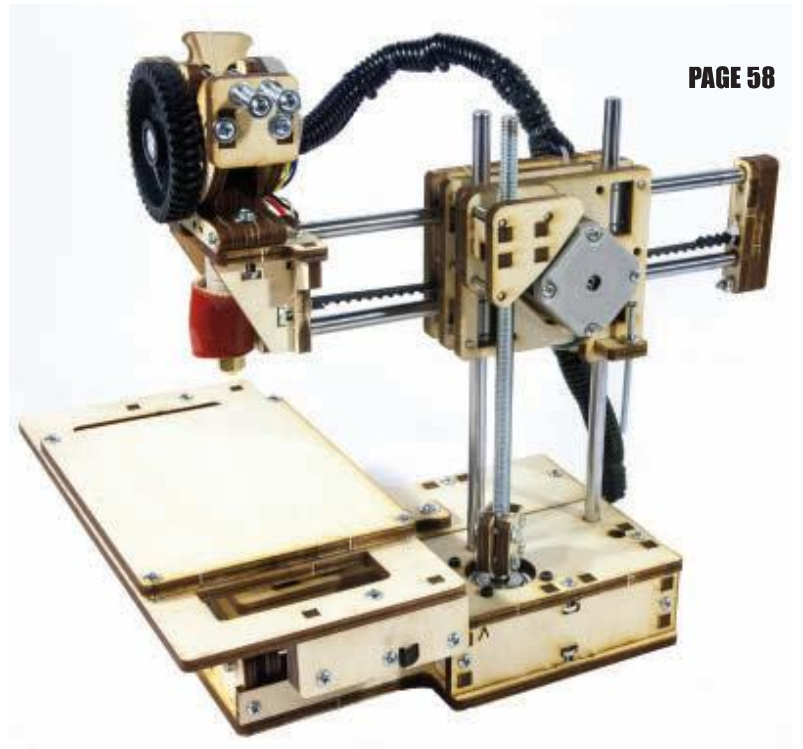
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The Internet of Things

The promise of intelligent objects — from shoes that tell you not only how many calories you've burned but when it's time for a new pair, to sensor networks in your lawn that tell your sprinkler system exactly when and where to direct water — has been slow in coming. However, it seems like we're finally there, in the form of the IoT, or the Internet of Things.

As a robotics enthusiast, you're probably intimately familiar with the three main elements of the IoT: sensors, embedded processors, and communications links. Two additional elements — rarely identified directly but understood — are affordability and miniature form factor. Clunky, expensive hardware just doesn't cut it when it comes to developing practical IoT systems.

Although bleeding edge micro-IoT is in the hands of the military and deep-pocketed corporate R&D shops, you can explore and contribute to the technology because of a tsunami of affordable microcontrollers, miniature power circuits, and MEMS sensors. For example, I'm working on an IoT pill dispenser that tracks when, where, and how many pills are taken. The MEMS sensors are so small that I'm using sensors pre-mounted on breakout boards for the prototypes. When I'm happy with the functionality, I'll mount the devices directly onto a miniature PCB of my design.

Power density is another factor. I've found the tiny LiPo battery packs sold for R/C helicopters and airplanes work well, as long as there is some means to easily and rapidly charge the battery. Scavenging energy from the environment — whether through solar radiation, Wi-Fi and cellular radio signals, body motion, or vibration — is still problematic. The most reliable environmental power source — the sun — isn't available 24/7.

Powerful, compact, affordable microcontrollers and microprocessors are leading the charge into IoT. Take the Raspberry Pi. For about \$30, you get an Internet-ready Linux computer that fits on virtually any robotic platform. For the same price, you can pick up a postage stamp-sized Arduino or Propeller board. I've had good experience with the ATMEGA 328-based Femtoduinos that has the same pinout layout (albeit on a smaller scale) as the Arduino Uno. The problem is the board doesn't have built-in communications.

On the communications front, the established player is the XBee module. While it's hard to beat for simplicity of setup — especially for a mesh or other network — it's getting long in the tooth in terms of footprint. There are cheaper, smaller alternatives for point-to-point communications. For example, I've had good results with the RFM12B-S2 wireless transceiver. The unit (available through SparkFun for \$7) operates in the 434 MHz band. You'll need to provide one unit with a connection to the Internet.

If you're using processing and Arduinos, one of the easiest means of getting your system on the Internet is to use an Arduino Wi-Fi shield. If the \$80 price tag is too steep for you, then wired Ethernet shields are another option. The merits of wired versus wireless connectivity to the Internet depends on the nature of the things you have on the Internet, as well as your budget.

If you think about it, it's now possible to create just about any intelligent object you can imagine, or that you've heard about. Take the smart refrigerator. It's no big deal as long as the three elements are available. And, of course, car manufacturers are having a field day with IoT. The DoD is experimenting with smart logistical systems that automatically track assets in real time. I'm sure that someone, somewhere is looking to replace the smartphone with some kind of IoT device that's more or less permanently associated with the body. I'm not ready to become an IoT device, but I suppose it's inevitable. **SV**

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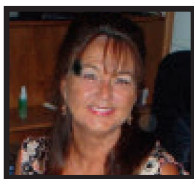
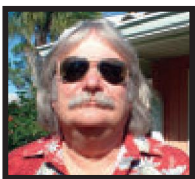
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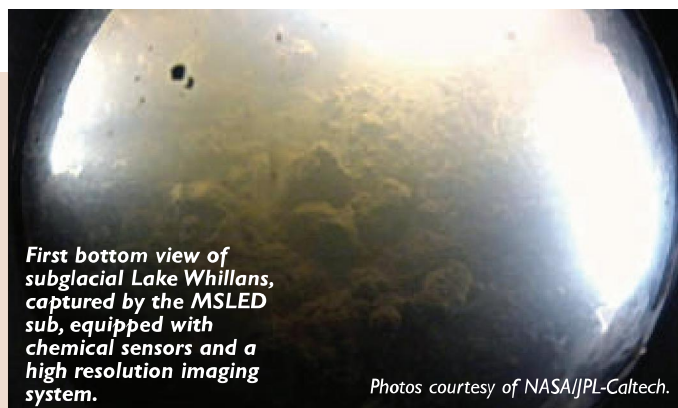


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Cold Sub, to Go

There isn't much left on the planet that has never been thoroughly poked, prodded, and analyzed yet, but one phenomenon that has largely evaded human curiosity is the subglacial lake. The term refers to a freshwater lake that exists beneath a glacier. Such things can exist only when a couple thousand meters of ice puts so much pressure on the water that it can remain fluid at sub-freezing temperatures. Accessing one presents some obvious challenges, but last January, NASA's Jet Propulsion Lab (www.jpl.nasa.gov) came to the aid of an international research team to make it all possible. Why NASA would be interested in the project may seem a little mysterious, but subglacial lakes are thought to exist on Jupiter's moon, Europa, so maybe they were just planning ahead.

In any event, the researchers spent three days using a hot water drill to create a borehole one foot (30 cm) in diameter and extending down through about 2,600 ft (800 m) of West Antarctica's Ross Ice Shelf into Lake Whillans. They then sent NASA's robotic Micro-Submersible Lake Exploration Device (MSLED) down to collect water samples and sediment cores. The baseball bat-sized sub was equipped with hydrological chemical sensors and a high resolution imaging system to detect exactly what is down there. Somewhat surprisingly, the researchers discovered that the lake water contains live bacteria, even though no sunlight can reach the 20 sq mi (52 sq km) body of water, so there must be something to eat down there. Details and multimedia are available at the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) site (www.wissard.org).



Photos courtesy of NASA/JPL-Caltech.

A student drops the MSLED robotic mini-sub into a 2,600 ft borehole that runs down to Lake Whillans.



Bots Built for Showbiz

A bot you're more likely to run into is RoboScreen — devised by Las Vegas denizen Andy "Robot" Flessas. In fact, if you happened to catch the Bon Jovi Circle Tour, you've already seen some of them acting as stage props that moved to the musical beat, and displayed animations and real time video. The mechanical part of a RoboScreen is actually a six-axis industrial robot produced by ABB Robotics (www.abb.com) which generally sells hardware and software for welding, handling, assembly, painting, palletizing, and so forth. In this case, ABB collaborated with Flessas to venture into the entertainment arena. You can choose from a range of robots (from the compact IRB 120 to the IRB 7600) and screen sizes (26 inches to 13.5 feet), plus two dedicated software plug-ins and a mixing board to address a "virtually unlimited range of entertainment and commercial applications."

These include live events and other entertainment venues, interactive point-of-purchase advertising, dramatic presentations in night clubs and sports bars, and even "kinetic architecture." Andy (who actually looks more like Elvis Costello) provides details at www.roboticarts.com.



Five RoboScreen devices being prepped for a Bon Jovi tour.
Photo credit: Robotic Arts.



One for Your Cat

If your problem is not so much a stinky musical act as a stinky kitty cat, the solution may be the Litter-Robot™ from Automated Pet Care Products, Inc. (www.litter-robot.com). You'll never sift, scoop, or bag kitty droppings again, as the poopbot does all the work for you. When your cat enters the porthole, a sensor detects his presence and prevents the device from operating until he leaves. While the patented sifter is in operation, the globe rotates slowly to discourage reentry. If the little sneak manages to get inside anyway, the machinery shuts off automatically.

The company emphasizes safety, noting that Litter-Robot runs off a modest 12 VDC, and there are no moving parts, sharp objects, or electrical wiring inside that could harm your pet. Plus, the waste drawer holds several days' worth of waste, so you can head out for a long weekend without worry.

The device is designed for cats weighing up to 15 lb (7 kg), but "larger cats have adapted to the Litter-Robot without problems." Plus, for an extra \$20, you can get the "bubble" version which provides extra elbow room and a view outside. The only obvious downside is that the standard model will run you \$339.99, which is probably considerably more than you paid for Tigger (including the neutering charges). **SV**



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GEER HEAD

by David Geer

Contact the author at geercom@windstream.net

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Hydroid's Deep Sea Marine-Exploring REMUS AUVs

*REMUS (Remote Environmental Measuring UnitS) poised and ready to
fathom areas of the ocean that remain untouched*

Hydroid, Inc., develops the REMUS AUVs used for plumbing the depths of oceans, seas, and marine environments. Each REMUS consists of like technology with subtle to not so subtle variations in their individual specs, depending on the particular application.

Several different navies globally use the REMUS line of AUVs with its high resolution remote spatial and temporal technologies for mine countermeasures, assessing climate changes that can affect ecological systems, hydrographic surveying, and much more.

I spoke with Hydroid to get the skinny on these cylindrical swimming automatons. Here's the scoop, Q&A style.

SERVO Magazine: What kinds of hydrographic surveying, climate change assessments, and mine countermeasures do the REMUS AUV robots actually perform? How do they collect the data?

Hydroid: Hydrographic surveys — Hydroid AUVs have been conducting high quality commercial surveys at low cost for more than 10 years. During this period, AUV technology has matured and advanced rapidly, up to a point where reliability and capability now combine to extend a ship's survey capacity — even making the ship itself redundant in some scenarios. AUVs — due to their ability to carry sensors close to the bottom on an acoustically quiet and non-intrusive platform — are ideal for many applications within offshore and hydrography.

REMUS AUVs are modular in construction, and allow for operators to insert plug-and-play payloads according to mission requirements. REMUS AUVs span the complete AUV product space — from man-portable shallow rated systems, to deep-rated survey grade systems with long endurance and enhanced payload capacity.

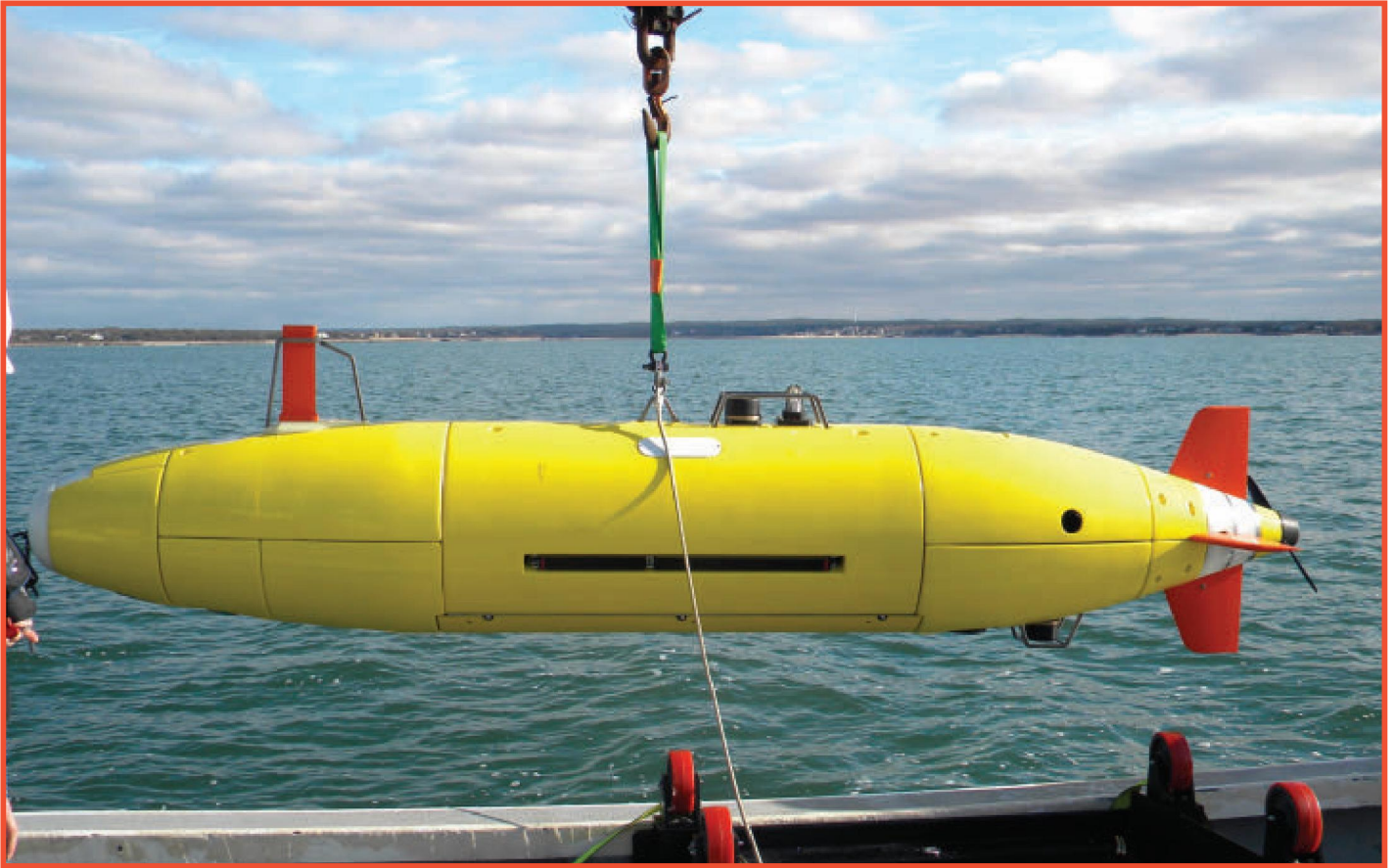
In traditional offshore surveying, AUVs have a proven

track record that has enabled survey companies to increase their profits by lowering costs, increasing production, and becoming more competitive. As AUVs continue to develop and mature, they can do several subsea operations that ROVs have traditionally handled. In particular, tasks like inspection, maintenance, and repair (IMR) of subsea structures and pipeline inspection have been the subject of strong focused R&D efforts for several years. Other areas of focus are environmental monitoring, under-ice survey, and hydrography.

Regarding Climate Change Assessments — The oceans are a leading indicator of climate change; climate change affects them and they, in turn, affect the climate. Physical oceanographers use AUVs to study these changes and assess their impact on our future — including the harshest environments on Earth: the poles and the deep ocean. Hydroid's AUVs offer technologies and capabilities that can access these areas and collect the highest quality data.

Regarding Mine Countermeasures — The first recognized use of AUVs as part of a live mine countermeasures (MCM) operation occurred in March 2003, when US Navy mine warfare elements deployed as part of Operation 'Iraqi Freedom' took the Hydroid REMUS 100 system into the warm shallow waters of the Northern Arabian Gulf and used its sidescan sonar to systematically map the approaches into the port of Umm Qasr.

Regarding How They Collect the Data — The operators send the vehicles out on missions with pre-configured



instrumentation packages. During the mission, the vehicles will store all the instrument, navigation, and vehicle status/health data on internal hard drives. After the operators recover the vehicles, they transfer the data to shipboard computers for analysis. The advantage of an AUV versus shipboard systems is that the AUV can take its samples in the optimum location for collection.

SM: The REMUS AUVs are self-powered; how so?

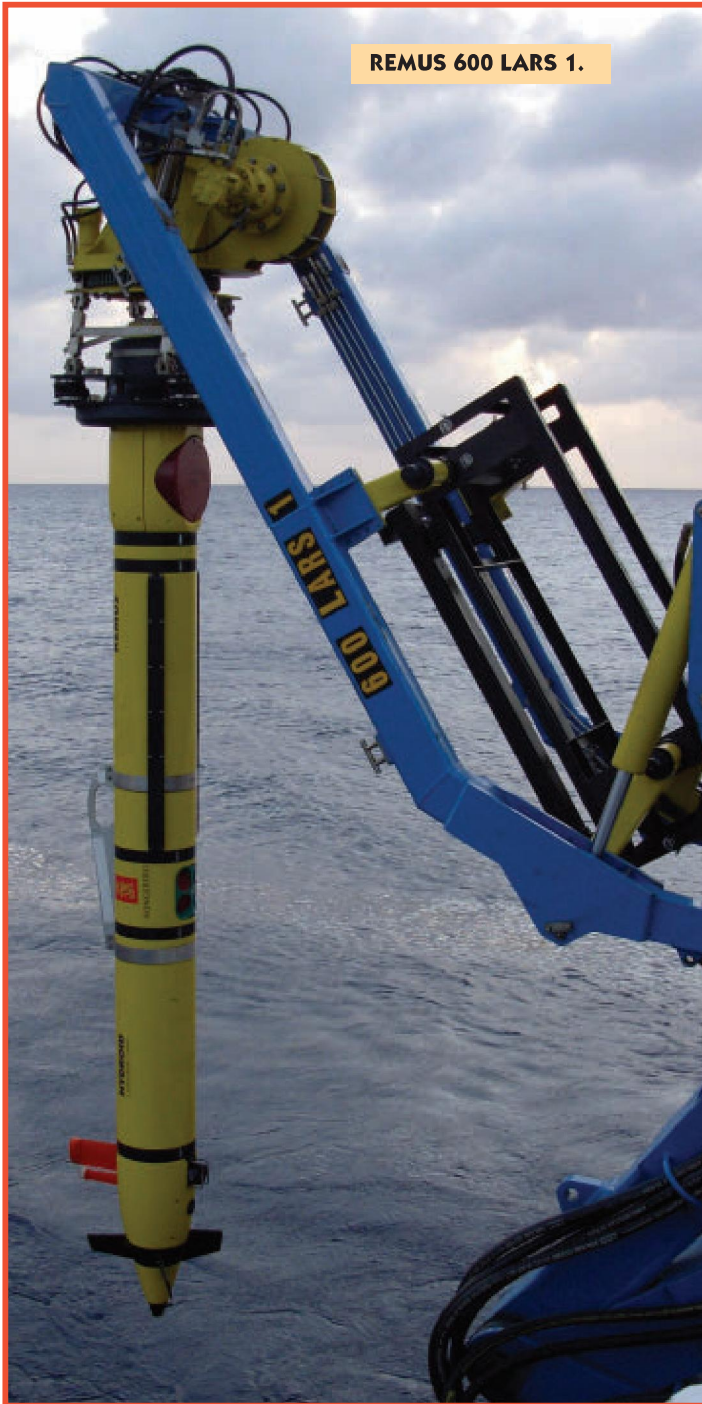
Hydroid: Each series of the REMUS AUV robots are powered in their own way as follows: The REMUS 100 has a 1 kWh internally rechargeable lithium-ion battery; the REMUS 600 has a 5.4 kWh rechargeable lithium-ion battery (a second 5.4 kWh battery tray is optional); and the REMUS 6000 has a 11 kWh rechargeable lithium-ion battery pack in two pressure housings (a second field-exchangeable 11 kWh set is provided).

SM: This paragraph from your published materials about Hydroid

R&D looks interesting:

"Hydroid's R&D efforts have focused on enabling AUVs to operate multiple payload sensors simultaneously, enabling the real advantage AUVs offer over traditional





REMUS 600 LARS 1.

survey methods. Researchers have also focused on lowering the platform's noise floor (electrically, acoustically, and magnetically), as well as carefully selecting payload sensor frequencies and managing their synchronization."

Could you expound on this?

Hydroid: Certainly. With the REMUS 100-S and REMUS 600-S, Hydroid has leveraged the experience of its R&D team, combining it with the ongoing efforts of its parent company, Kongsberg Maritime, to produce vehicles that are capable of collecting data up to the International

Resources

www.youtube.com/watch?v=LEe5RLx3kII&feature=plcp

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Hydrographic Organization (IHO) standards. In particular, Hydroid has synchronized sample collection timing for each instrument (sonars, motion senses, etc.), down to the millisecond to enable comparison of all data at the exact same moment. For hydrography, this is especially important as knowing the exact orientation and position of the vehicle at the time of a sounding leads to better charts of the sea floor.

Operators can run the REMUS AUVs completely autonomously from a surface ship. Therefore, the surface ship is free to conduct survey operations in a different area than the AUV, resulting in a large increase in mapping production. Also, to take it one step further, one operator could have up to four REMUS vehicles working from the same vessel/communications platform. Therefore, the user could have up to five concurrent mapping operations (four AUVs + one surface ship) taking place from a single platform, yielding a massive increase in productivity and efficiency.

SM: Please discuss the Vehicle Interface Program (VIP) that operators use in conjunction with the REMUS AUVs.

Hydroid: All REMUS vehicles essentially use the same basic VIP, which consists of software housed in a ruggedized laptop computer and hardware housed in the vehicle. Hydroid has customized the VIP to reflect the exact configuration of sensors for each vehicle. This highly intuitive VIP allows anyone to become an AUV operator with just a few days of training. It greatly simplifies vehicle maintenance, mission planning, vehicle checkout, and data analysis; it will run on any PC or laptop operating under Windows® 95, 98, NT, 2000, or XP. The system conducts communication between the vehicle and the host via a standard Ethernet connection.

Among other features, the VIP includes: an integrated text editor for construction of the mission file; a map view that illustrates the planned mission for review; automatic error checking performed on all aspects of the planned mission with warning messages that appear if any mission parameters are incorrect; and a set of quick-look indicators display system status where green indicates okay, and red indicates a fault.

SM: How would you describe the larger effect of your progress in the area of military domination of seas and

oceans as referenced in the following citation from your materials?

"Hydroid dominates the military market domestically and internationally. In addition, Hydroid has more AUVs in the field than all five of its competitors combined. Fourteen navies around the world use a REMUS AUV. Since 2001, Hydroid has seen a six-fold increase in the number of AUVs sold per year. Hydroid has delivered more than 230 AUVs to domestic and international customers since it was founded in 2001, with an annual average of approximately 23 vehicles. In addition, the REMUS AUV is the first and only unmanned vehicle that a fleet has used in a time of war — both the Royal Navy and the US Navy employ Hydroid AUVs."

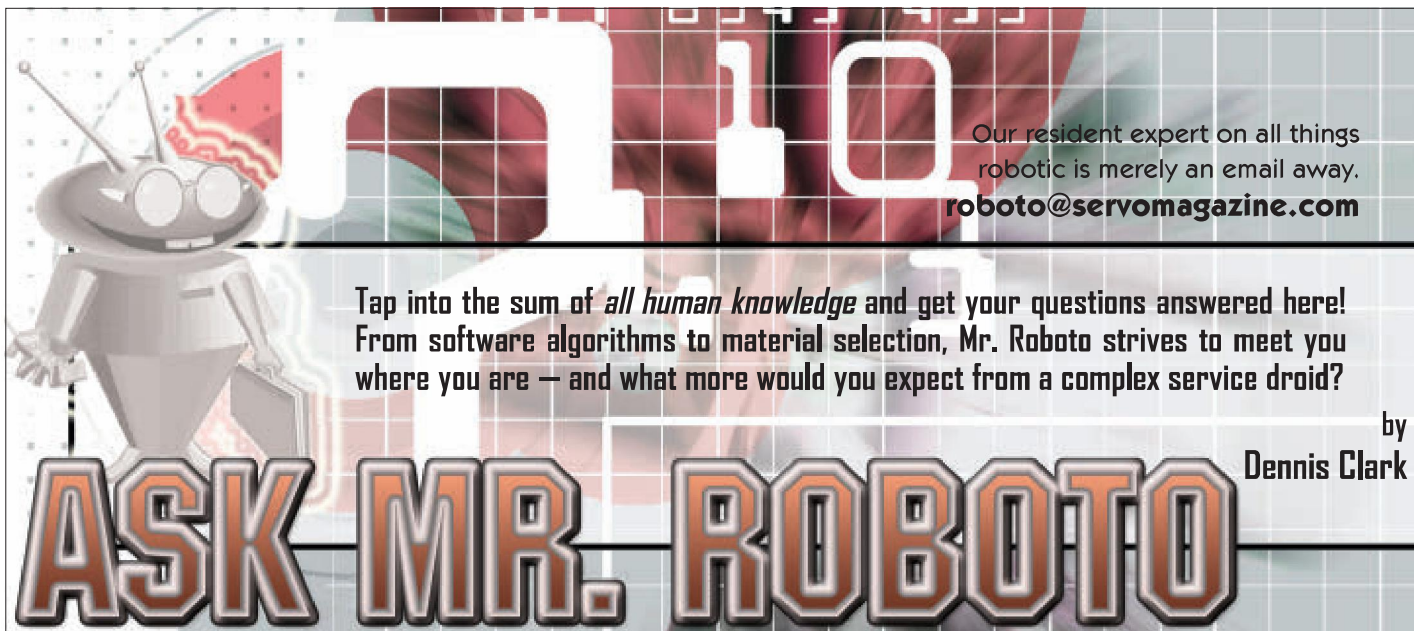
Hydroid: AUVs offer a unique set of advantages to navies, including the following. **Coverttness:** AUVs can perform their tasks without revealing their presence to hostile forces, thus maintaining the element of surprise. **Safety:** AUVs can operate in high risk areas such as mine fields or enemy controlled waters, while operators can position manned platforms in relative safety for much of the operation. **Data quality:** AUVs normally operate underneath the difficult surface layers, placing the sensors in an optimal position. Compared to most other platforms, AUVs provide smooth and linear trajectories, further increasing sensor data quality. **Speed:** The larger AUVs allow rapid collection of very high quality data with area coverage rates of around 2 km²/hr. **Force multiplication:** AUVs improve the value of existing assets by allowing the mothership to perform one task while the AUV performs another.

AUVs are capable of performing a wide range of naval operations, such as: mine counter measures (MCM); rapid environmental assessment (REA); intelligence, surveillance, target acquisition, and reconnaissance/ISTAR; route survey; surveillance; harbor protection; and anti-submarine warfare (ASW).

Conclusion

Hydroid REMUS AUVs are certainly entrenched in the marine exploration industry and are here to stay. For more information, see the video links under Resources. **SV**





Tap into the sum of *all human knowledge* and get your questions answered here! From software algorithms to material selection, Mr. Roboto strives to meet you where you are — and what more would you expect from a complex service droid?

by
Dennis Clark

All the code is available at the article link, so typing it in manually as mentioned in the article is not necessary ... unless you really like to type.

This month, I had a few very interesting questions dealing with motors, Dynamixel servos, and the Raspberry Pi computer. I started with the Raspberry Pi question thinking that it should be a simple task — "It's Linux, how hard can that be?" Okay. Never tempt the gods by leading with your chin! The Raspberry Pi kind of took over my time — WAY took over my time — so I'll let that be my topic of discussion this month.

It is now May, and the season for thinking about upcoming robot competitions here in the US. You are thinking about them, right? I sure am — I'm thinking about how little time is left and how much there is to do! I have this advice for you, who may be thinking about this too: Pick your battles carefully! You can't do it all. Pick the one or two competitions that mean the most to you and perhaps,

maybe the most accessible to you. You will get more done and have more fun if you follow that simple rule. There are two other tidbits of advice I will give you. If it isn't written down, it doesn't happen. You need to record your plans and your path forward. If it resides only in your head, it just won't happen. You need to have something clear and concise to refer to or you can't tell where you are or what you have to do next. Finally, an aphorism to live by when you are a hobbyist: "The hardest part of any project is the first one." You can talk about, dream about, write about a project, but until you start it, it won't get done. We know this, but for many of us, that first step is the hardest part to do. Once you start, your work falls into line; until you start, it is nothing. Think about it. Onward ...

creating your OS for your Pi is <http://raspberrypi.org/downloads>. There are a few different flavors; the one that I chose is the Wheezy "Soft Float ABI" so that I could use Java or Mono (open source C# compiler) to do interesting things with cameras some day.

The stock Wheezy uses a "Hard Float ABI" which is faster in some ways. The difference between these is all about how a floating point number is moved around the system.

As most of my readers know, I am a Mac OS X guy — not Windows — so I went to: <https://github.com/RayViljoen/Raspberry-PI-SD-Installer-OS-X> to get a Pi installer script setup that put my Pi OS onto my SD card. It worked very simply and very well! I won't go into the details (it takes a long time) since that isn't what this question is about.

It will suffice to say that when that script finishes, you'll have a bootable Raspbian OS created. Of course, the OS will be many months out of date (why don't they keep those installs up to date? I don't know!), and you will need to update it to create the 512 MB capable kernel and system. I'll go through the steps necessary here, but before you start, know this: This will take a long time; by which I mean it will take an hour or perhaps two to complete the process. Flash card writing is not as

Q. I have a new Raspberry Pi that has 512 MB of RAM, but I can only see 256 MB of RAM when I run it. I've tried a few of the steps that I've found online, but nothing seems to work. How do I tell if my board is actually 512 MB or if I'm just not doing something correctly?

— Tony (via email)

A. There are a few paths that you can take. Obviously, you have gotten your OS installed on your Raspberry Pi or you wouldn't be wondering where your extra RAM went! Okay, it is going to be tedious to keep typing (and reading) Raspberry Pi, so from now on I'm going to shorten it to "Pi." For others of you out there wondering where you start, the place to go when

fast as hard drives and the Pi is not as fast as your Intel i7 computer! I'll tell you a little more of what happens when you first boot your Pi with your newly-minted OS SD card. Raspi-Config will come up to get you to do a few housekeeping tasks. Do the following:

1. *expand_rootfs*: This is so you get your full 4GB of "disk" space.
2. *configure_keyboard*: This is so your system understands your keyboard.
3. *change_timezone*: This is so your system time will be correct.
4. *ssh*: This enables ssh so we can log in from another machine.

After you do these things, go ahead and reboot. Your journey has just begun ...

Before I answer your first question and start you down the path of an hour or two of waiting for updates and upgrades, I want to answer your second question first. How do you know that your Pi board is really 512 MB? I searched the Web for an answer to this question and found many false leads and downright incorrect answers, but eventually, I found "gold."

Look at the big chip in the middle of the board. Mine says "K4P4G324EB-A6C1" — I have a 512 MB unit. This apparently is only the Samsung RAM part number, or "top of the stack" or something like that. Hours of Googling has not really shone a bright light on part number translations.

Regardless, after the "K4P" are the digits "4G;" this means 4 Gigabits of RAM, which translates into 512 MB (bits/8). A "2G" would have meant 2 Gigabits, or 256 MB of RAM. Now you *know* you have 512 MB of RAM. The next step is to enable it!

As I had mentioned before, I spent many hours searching the Web for the definitive means by which I could enable that extended RAM in the Pi. I found many answers to the question. I found several that just plain didn't work; some that partly worked; and a couple that trashed my SD card or left me in a state where my OS got "glitchy" and caused me to rebuild it — which wasn't that difficult (fortunately).

Before we know we have gotten to the place we want to be, we need to know where we are **now**. So, after your Pi has booted and you've logged in, execute the following command. Here is (more or less) what you should get:

```
pi@raspberrypi ~ $ free -h
total      used      free      shared    buffers     cached
Mem:
183M       49M       134M        0B         7.5M        23M
-/+ buffers/cache:
        18M       165M
Swap:
 99M        0B        99M
pi@raspberrypi ~ $
```

The total RAM available to our Pi is 183 MB. Remember that the Pi processor is actually an ARM processor and a

graphics co-processor. The Pi system defaults to giving 64 MB of RAM to the Graphics Processing Unit, leaving the OS with the rest. There is about 9 MB that doesn't seem to show up. I'm not sure just where it goes, but it isn't in this output. We want more RAM, and this shows us where we start.

To show how we accomplish this, I'm going to borrow from a few sites and some readings from man pages. (In Linux-land, "man" pages are "manual" pages which tell you what commands are and how to use them.) Man pages are not for the faint at heart and are filled with UNIX hacker jargon. If you are going to use Linux, get used to it; they are your first step to take to get something done. Man pages are filled with facts and are typically correct — unlike many places on the Web (smile when you say that!).

The site <http://hubcitylabs.org/unlocking-your-new-raspberry-pis-512mb-of-memory> came the closest to working for me, but it left out a few "gotchas" with the scripts and descriptions. I'll try to fill in those spaces for you, since I've stumbled over every mistake possible while implementing them!

WARNING: Getting these wrong means starting over and making a new OS install, so don't do this without saving your work and documenting what you have there! If you have the option, practice on a new, fresh install first!

The next Linux command you need to know and use is *sudo*. This allows a user — like *pi* — to access *root* administrator processes and settings. You'll do everything in this update sequence with *sudo*.

The first Linux utility that you need to become comfortable with is *apt-get*. This command is how you update your OS, add programs, programming environments, optional functionality, drivers, you name it. Linux *apt-get* is an amazing piece of software. It is able to check any dependency that the package may have, and suggest the correct install to satisfy it. I've grown almost religious in my trust of this well designed program and its underpinning!

Ready? Let's go!

Type the following command (results shown):

```
pi@raspberrypi ~ $ sudo apt-get update
Get:1 http://archive.raspberrypi.org wheezy
      InRelease [7,737 B]
Get:2 http://http.debian.net wheezy InRelease
      [224 kB]
Get:3 http://archive.raspberrypi.org wheezy/main
      armel Packages [4,332 B]
Get:4 http://http.debian.net wheezy/main armel
      Packages [5,720 kB]
Get:5 http://http.debian.net wheezy/contrib
      Translation-en [34.9 kB]
Get:6 http://http.debian.net wheezy/main
      Translation-en [3,854 kB]
Ign http://archive.raspberrypi.org wheezy/main
      Translation-en_GB
Ign http://archive.raspberrypi.org wheezy/main
      Translation-en
Get:7 http://http.debian.net wheezy/non-free
      Translation-en [66.0 kB]
Get:8 http://http.debian.net wheezy/contrib
```

```
armel Packages [34.0 kB]
Get:9 http://http.debian.net wheezy/non-free
armel Packages [57.8 kB]
Fetched 10.0 MB in 1min 23s (120 kB/s)
W: Failed to fetch
bzp2:/var/lib/apt/lists/partial/http.debian.net_
debian_dists_wheezy_main_binary-armel_Packages
Hash Sum mismatch
```

```
E: Some index files failed to download. They
have been ignored, or old ones used instead.
pi@raspberrypi ~ $
```

apt-get update gets all the latest information about all of the installed and installable packages that you can put on your Pi. It goes out on the network to do this and talks to a bunch of sites which it listed. **If there are failures — especially bzp2 — reboot and try again.**

After you get the most recent version information about your system, you need to upgrade to those versions. **Reboot before attempting the next step.**

```
pi@raspberrypi ~ $ sudo shutdown -r now
Broadcast message from root@raspberrypi (pts/0)
(Sun Mar 31 21:56:17 2013):
The system is going down for reboot NOW!
Connection to 192.168.1.114 closed by remote
host.
Connection to 192.168.1.114 closed.
```

Type the following to do your upgrade:

```
pi@raspberrypi ~ $ sudo apt-get upgrade
```

Answer using the upper case “Y;” I’ll talk about this later. This could take a long time, so go have supper after you answer. My first time through this took about 10 minutes. I’m not sure what went wrong. The second time it took nearly an hour. **If this doesn’t take you a long time (depends upon your network speed), it didn’t work. Reboot. Do another apt-get update. Reboot, and try again. Reboot** to make sure all is upgraded and installed. Do this by:

```
pi@raspberrypi ~ $ sudo shutdown -r now
Broadcast message from root@raspberrypi (pts/0)
(Sun Mar 31 21:56:17 2013):
The system is going down for reboot NOW!
Connection to 192.168.1.114 closed by remote
host.
Connection to 192.168.1.114 closed.
```

After the update and upgrade have been run, we will need to update the boot firmware. Think of this as updating the BIOS on your Windows PC. To do this, we use some scripts developed by a fellow whose handle is “Hexxeh” and whose code is at **https://github.com/Hexxeh/rpi-update**.

It works, I am very pleased to say! However, you have to be VERY careful when using these instructions. I found that some of the scripts either here or with *apt-get* scripts may not take a lower-case “y” as the same answer as an upper case “Y.”

Here is the magic; type this exactly:

```
pi@raspberrypi ~ $ sudo -i
```

```
rm -rf /boot/*.elf /boot/*.bin /boot/*.img
apt-get install git
apt-get install ca-certificates
wget http://goo.gl/1BOfJ -O /usr/bin/rpi-update
&& sudo chmod +x/usr/bin/rpi-update
```

The *sudo -i* puts you into the root shell so that you don’t need to keep using *sudo* on every command. The *apt-get install git* will ask you if you want to proceed, the *apt-get install ca-certificates* may say you already have the most recent ones. Now, we get to the heart of the matter — the one that caused me the most trouble: the *wget* line with the weird http site name.

wget **http://goo.gl/1BOfJ -O**

this is, phonetically speaking: Gee Oh Oh dot Gee Ell slash number One capital letter Bee capital letter Oh lower case letter Eff capital letter Jay.

If you mistype that, you will get a file, but it will be an html file that will NOT run on the command line! Trust me! Here is the expected output of this sequence of commands:

```
root@raspberrypi:~# wget http://goo.gl/1BOfJ -O
/usr/bin/rpi-update && sudo chmod +x
/usr/bin/rpi-update
-2013-03-31 22:10:15- http://goo.gl/1BOfJ
Resolving goo.gl (goo.gl)... 74.125.225.164,
74.125.225.165, 74.125.225.168, ...
Connecting to goo.gl (goo.gl)|74.125.225.164
|:80... connected.
HTTP request sent, awaiting response... 301
Moved Permanently
Location: https://raw.github.com/Hexxeh/rpi-
update/master/rpi-update [following]
-2013-03-31 22:10:15-
https://raw.github.com/Hexxeh/rpi-update/master/
rpi-update
Resolving raw.github.com (raw.github.com)...
199.27.73.133
Connecting to raw.github.com (raw.github.com)|
199.27.73.133|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 6198 (6.1K) [text/plain]
Saving to: `/usr/bin/rpi-update'

100%[=====>]
6,198 --K/s in 0.002s

2013-03-31 22:10:20 (2.44 MB/s) -
`/usr/bin/rpi-update' saved [6198/6198]

root@raspberrypi:~#
```

This next command will take an hour or so to complete, so go watch an episode of *Robot Combat League* or something after you hit enter:

```
pi@raspberrypi:~$ sudo /usr/bin/rpi-update
```

After the boot firmware update completes, **reboot** again. This runs the new firmware that allows Raspbian Wheezy to access all of the RAM that the board has. To prove it, we will run the very first command that we ran to see what kind of memory we have.

Type the following:


```

pi@raspberrypi ~ $ free -h
total        used        free
Mem:
438M          107M          331M
shared        buffers        cached
0B             14M          48M
-/+ buffers/cache:
              44M          393M
Swap:
99M           0B           99M
pi@raspberrypi ~ $

```

We have left the GPU with the default setting of 64 MB of RAM, which allows reasonable performance for the lean X11 user interface (that you can start with *startx* as you are told every time you boot up). In fact, the *free -h* results I show above are when I'm running X11 with two terminal windows open. You can change this by editing the */boot/config.txt* file, and adding or subtracting to that default 64 MB. Use your favorite Linux text editor (I prefer "vi") to edit */boot/config.txt*, and add this line:

```
gpu_mem_512=16#for 16MB to the GPU, or whatever you want.
```

Whew, I believe that I have answered your question. It is not a simple — nor apparently a very repeatable — procedure to do this. We can only hope that the good folks making these install packages soon release one that has this taken care of so we don't have to do it ourselves. Maybe they will have it by the time you read this, and the only thing that you will have to do is the very last step.

Well, that is another Mr. Roboto column for your enjoyment and edification. I hope that this helps someone out there! I love hearing from you, so remember, if you have a robot question please drop me an email at roboto@servomagazine.com and I'll do my best to answer them. Until next month, keep on building robots! **SV**

If you really want lots of useful "how to" details and places to find more information about your Raspberry Pi, I recommend the book *Getting Started with Raspberry Pi*, by Matt Richardson and Shawn Wallace.

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EVENTS

Calendar

ROBOTS.NET

Send updates, new listings, corrections, complaints, and suggestions to: steve@ncc.com or FAX 972-404-0269

Know of any robot competitions I've missed? Is your local school or robot group planning a contest? Send an email to steve@ncc.com and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, send along the URL as well, so we can tell everyone else about it.

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net:

<http://robots.net/rcfaq.html>.

— R. Steven Rainwater

MAY

- 3** **SPURT**
University of Rostock
Rostock-Warnemunde, Germany
Autonomous robot race on the SPURT track. SPURT stands for School Projects Using Robot Techniques.
<http://spurt.uni-rostock.de>
- 3-4** **RoboRave**
Albuquerque, NM
Events include fire fighting, line following, and jousting for autonomous robots, and Robotovate for tele-operated robots.
www.roborage.org
- 3-4** **Swiss Eurobot**
Sion (Valais), Switzerland
Regional event for the Eurobot autonomous robot challenge.
www.swisseurobot.ch
- 6-10** **ICRA Robot Challenge**
Karlsruhe, Germany
Events include Micro-Robot Challenge, Virtual Manufacturing Challenge, Solutions in Perception Challenge, and Modular and Reconfigurable Robot Challenge.

www.icra2013.org

- 6-12** **Eurobot**
France
Autonomous robot challenge that varies each year. See the website for details on this year's challenge.
www.eurobot.org
- 11** **DPRG Roborama**
Dallas, TX
The Dallas Personal Robotics Group's bi-annual autonomous robot competition.
www.dprg.org/competitions
- 11** **Western Canadian Robot Games**
Calgary, Alberta, Canada
Lots of events including Sumo, mini Sumo, line following, LEGO Mindstorms, humanoid and walker challenges, art bots, and an off-road contest.
www.robotgames.com
- 13** **RoboFest**
Lawrence Technological University, Southfield, MI
Events include co-operative two-robot games, a robot exhibition, and a vision-based robot challenge.
<http://robofest.net>
- 18** **CybAiRBot**
Poznan, Poland
Autonomous Sumo competition.
www.sumo.put.poznan.pl
- 18** **National SeaPerch Challenge**
Indianapolis, IN
Students build open hardware underwater ROVs to compete.
www.seaperch.org/seaperch_challenge
- 20** **NATCAR**
UC Davis Campus, Davis, CA
High speed variation on line following in which the line is a wire producing a 75 kHz magnetic field.
www.ece.ucdavis.edu/natcar

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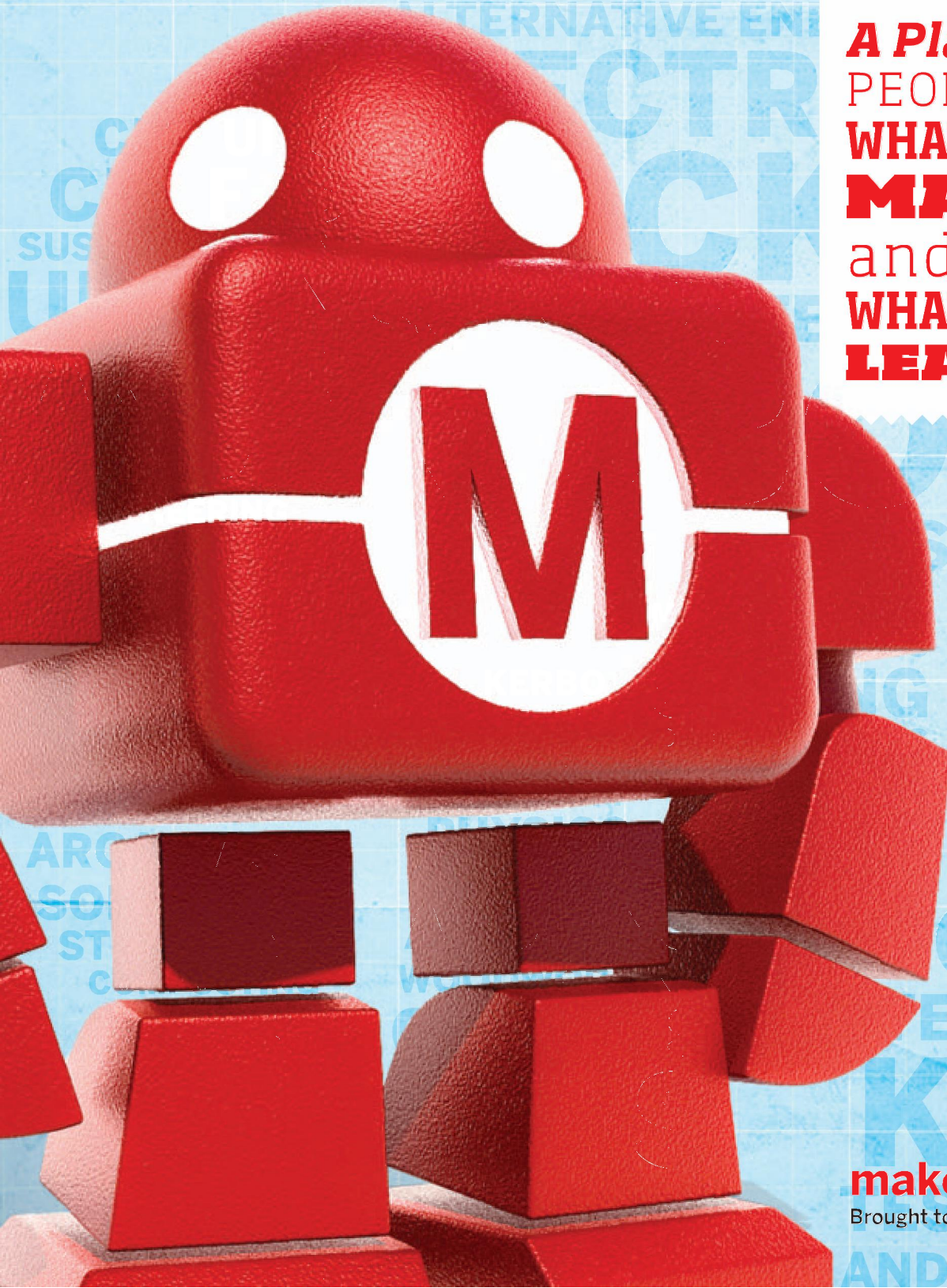
MAY 18–19



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NEW PRODUCTS

Beam Attachment Blocks

ServoCity's aluminum beams have become a popular way to create custom links and connectors, and their new beam attachment blocks introduce even more design possibilities. Like the beams, the attachment blocks are constructed of 6061-T6 aluminum for strength and rigidity. The beams have 6-32 thru-holes that are spaced to be compatible with the 0.770" hub pattern found throughout the ServoCity product line.



The beam attachment blocks have one 6-32 tapped hole for mounting the block, and one 6-32 thru-hole for creating links. The photo shows the beam blocks joining ServoCity's new channel to the beams using 6-32 socket head screws and nylock nuts. For a rigid structure using the beams and blocks, tighten the nylock nuts completely. For a movable structure, slightly tighten the nuts. Price is \$4.99/four-pack.

Ball Bearing Pillowblocks

ServoCity is also offering new Pillowblocks to make it simple to integrate a ball bearing component into a project. The frame is constructed from 6061-T6 aluminum and the precision ball bearing is stainless steel, ensuring that the Pillowblock won't flex or bow.

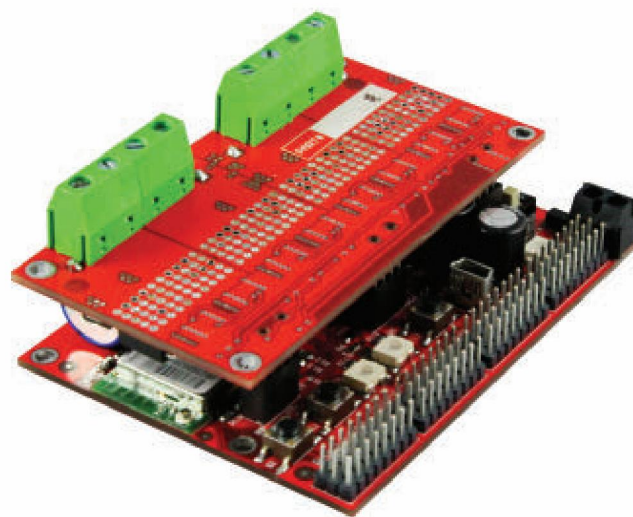


Both dual mount and quad mount Pillowblocks are offered in a variety of bore sizes, ranging from .250" to 1.00". The 6-32 tapped mounting holes are spaced 1.061" apart, allowing for easy attachment to ServoCity's aluminum channel and many other parts that utilize the channel hole pattern. Prices start at \$5.99/each.

For further information, please contact:

Wi-Fi Enabled Robot Controller

Robotics Redefined, Inc./Fedora Labs announces Renegade: an easy-to-use, full-featured Wi-Fi enabled robot controller. Renegade harnesses the processing power of 16-bit microcontrollers with 32 general input/output channels. These channels are easily configured to connect up to 32 servos or digital input/output devices.



Renegade also features eight ADC channels and two quadrature encoder channels. It comes complete with an external easily attached motor driver shield, available in either high amp or low amp versions. With the motor driver shield attached, Renegade can run up to four DC motors with current and temperature monitors. This shield can also be used to drive other high current devices like relays and solenoids.

Renegade provides a high level of wireless control. Upon activation, Renegade automatically establishes a wireless network allowing for immediate configuration of the I/O ports through a web browser. Controlling the Renegade is then a matter of sending simple, intuitive commands to the robot over UDP. This can be done in any programming language on any platform including — but not limited to — C, C++, Java, C#, PHP, and Python from any wireless device (including laptops, iPads, and smartphones).

For beginners or enthusiasts who are not interested in programming, Fedora Labs has provided a GUI that allows the user to explore many of the features and capabilities of the Renegade. For those who would like to create their own control programs, Fedora Labs has also provided the source code for their user-interface program, as well as other code samples to serve as reference examples.

The processing power of the 16-bit microcontroller, the versatility of 32 fully customizable I/Os, the ability to run four DC motors at up to 60A, and the freedom of easy wireless configuration and control combine to make the Renegade an ideal component of any robotics project. Rather than scouring retailers for a mix of components and hoping they are compatible, the hobbyist can find in the Renegade a complete control system that can handle any assortment of devices. Ideal for students and educators, the Renegade provides a platform by which the user determines their own level of intensity. For beginners, it's a plug-and-play robot control system complete with a ready-made user interface program; for experts, it's a blank slate offering completely customizable hardware, software, and operation.

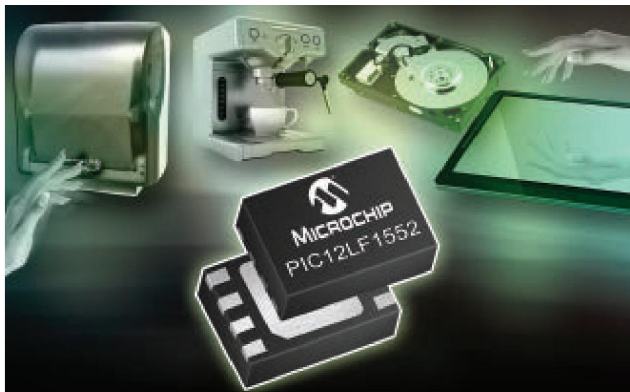
For further information, please contact:

**Robotics Redefined/
Fedora Labs**

Website: www.federalabs.com

Smallest and Lowest Cost PIC With I²C

Microchip Technology, Inc., has announced a new addition to its PIC12/16F15XX eight-bit microcontroller (MCU) family. The low cost, low pin count PIC12LF1552 is Microchip's smallest (2 x 3 mm UDFN package) and lowest cost PIC MCU with hardware I²C support, and includes a four-channel 10-bit analog-to-digital



converter (ADC) with hardware capacitive voltage divider (CVD) support for capacitive touch sensing. Additionally, this new MCU features 3.5 KB Flash program memory, 256 bytes RAM, a 32 MHz internal oscillator, low voltage operation from 1.8V to 3.6V, and low power consumption for active and sleep currents of 50 μ A/MHz and 20 nA, respectively.

The hardware CVD enables a more efficient implementation of capacitive sensing for touch applications. This "core-independent peripheral" includes additional control logic that enables automated sampling which reduces software size and minimizes CPU usage. It also

provides automatic control of guard-ring drive and a programmable sample-and-hold capacitance to better match larger touch or proximity sensors. These capabilities, combined with the low cost and small footprint of the PIC12LF1552, make it well suited for applications such as temperature monitoring devices, small remote controls, smartphone buttons, room light control, and water-level monitoring, among others.

Microchip's full suite of development tools support the PIC12LF MCUs, including the MPLAB® X Integrated Development Environment (IDE), and PICKIT™ 3 (part #PG164130, \$44.95), MPLAB REAL ICE™ In-Circuit Emulator (part #DV244005, \$499.98), and MPLAB® ICD 3 (part #DV164035, \$189.99) programmers. Additionally, the MPLAB XC8 Compiler for 8-bit PIC MCUs now supports this device. The PIC12LF1552 MCU is offered in eight-pin PDIP, SOIC, MSOP, and 2x3x0.5 mm UDFN packages. It is available in volume production.

For further information, please contact:

**Microchip
Technology, Inc.**

Website: www.microchip.com

Motorcar Powered By Flexible Polycrystalline Silicon Solar Cell

ToyLabs, Inc., is now offering the Volta Racer which is packaged with prefabricated components necessary to build and power the solar powered vehicle. The racer can be put together in as little as 15 minutes with no special tools.

By assembling the Volta Racer, kids will learn basic



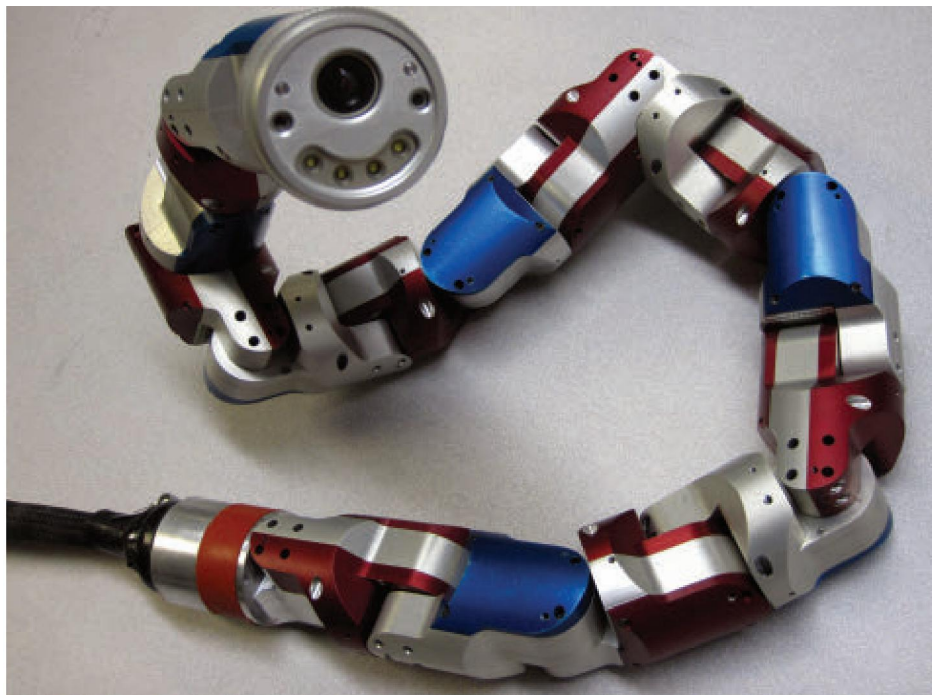
concepts and principles of solar electricity and mechanical engineering. The Volta Racer operates at normal and high speeds, and can traverse various surfaces and terrains. The vehicle has a very unique feature: a flexible polycrystalline silicon solar cell. The curvature of the solar cell allows the car to capture more of the sun's energy from numerous angles. The car also employs super lightweight, eco-friendly recyclable materials.

For further information, please contact:

Toylabs, Inc.

Website: www.toylabs.com

bots IN BRIEF



THESE SNAKES WILL CHARM YOU

Snake robots are cool. They slither. They swim. They shoot lasers with their mouths. Researchers often say that snakebots are great for search and rescue applications. You send one into a disaster site and use its cameras to see what's going on there. However, with all the slithering and rolling and undulating, watching through a snakebot's eyes might be a nausea-inducing experience.

Now, the folks at the CMU Biorobotics Lab might have a solution. Their snake robot can point its head in a desired direction while climbing on a pole. The whole body moves; the head doesn't.

Snake robots can use their many internal degrees of freedom to thread through tightly packed areas, accessing locations that people and machinery otherwise cannot.

Moreover, these highly articulated devices can coordinate their internal degrees of freedom to perform a variety of locomotion capabilities that go beyond the capabilities of conventional wheeled and recently developed legged robots. The true power of these devices is that they are versatile, achieving behaviors not limited to crawling, climbing, and swimming.

Check out videos at www.cs.cmu.edu/~biorobotics/projects/modsnake/index.html.

BTW, the snake names are: Uncle Sam, Frostbite, Molly, Spooky Snake, and Pepperoni.



bots IN BRIEF

CHIMP NO CHUMP

It has only been a few months since DARPA announced the teams competing in its upcoming Robotics Challenge, but already some of the robots are beginning to shape up. Take, for example, the exotic looking CHIMP robot built by a team at Carnegie Mellon University's National Robotics Engineering Center. CHIMP (CMU Highly Intelligent Mobile Platform) features tank-like treads on its arms and legs for tackling the bumpy terrain it will encounter as part of the challenge. The idea is to take advantage of both legged and wheeled locomotion, allowing the robot to scoot around low to the ground but stand up when necessary.

"When we walk or stand, our brains are actively controlling our balance all of the time," Tony Stentz, NREC director and the Tartan Rescue Team Leader, said in a recent statement. While famous bipedal robots like Honda's Asimo do a good job of replicating this behavior in structured environments like office buildings, it's a different story when they're faced with a steep, rocky hill. The CHIMP's unusual approach to locomotion should allow it to rapidly overcome these obstacles, even if it is only stable in a static way.

NREC's Tartan Rescue team is one of seven teams developing their own hardware and software from the ground up specifically for the DARPA Robotics Challenge. Each of those seven teams is taking a different approach to the design and functionality of their robots. A second group of teams will use a version of Boston Dynamics' humanoid robot, Atlas. One thing that all of the robots participating in the competition will share in common is that they're remote-controlled by people. "Humans provide high level control, while the robot provides low level reflexes and self-protective behaviors," said Stentz. "This enables CHIMP to be highly capable without the complexity associated with a fully autonomous robot. In a pinch, it can do anything."

The harsh reality for sci-fi fans is that today's artificial intelligence hasn't come far enough for robots to carry out chains of highly complex tasks without human assistance. An operator will control CHIMP using a keyboard and mouse at a workstation consisting of a large monitor displaying multiple video feeds from the robot's cameras, and software with shortcuts to easily shift from manual to autonomous control. The robot's sensors will generate a texture-mapped 3D model of its environment, enabling the operator to



visualize the robot's position relative to its surroundings.

A nice side-effect of building the robot is the development of new technologies — such as the proprietary drive joints in its arms and legs that possess near-human strength and dexterity — that can be implemented in a diverse range of robots such as those intended for manufacturing. That way, even if CHIMP doesn't take home the challenge's \$2 million top prize, the extensive R&D undertaken to build it should prove worthwhile.

If all goes well, robots like those developed for the challenge will one day take the place of people in life-threatening circumstances.

KINECT WITH GESTURE CONTROL



Not only is the Microsoft Research Cambridge team finally releasing their 3D modeling API Kinect Fusion, they're bringing you gesture control — with mouse clicks and multi-touch pinch-to-zoom interactions.

Current Kinect sensors can track joints in your body, but not small gestures; in particular, hand motions. But that's about to change. Using machine learning, Kinect can now recognize open and closed hands.

As developers explore this new Kinect API capability (and as Microsoft refines the level of gesture recognition beyond open and closed hands), the possibilities look exciting. We're all hoping, of course, to throw away our mouses and use computers like Tom Cruise did in *Minority Report*. The API will be released in the next Windows SDK.

FASTEST WORM IN THE WORLD

Meet the fastest miniature inchworm robot in the world — even though it uses just one single motor.

The mechanical design is pretty clever. Moving segments equipped with clamps alternately retract and extend, propelling the inchworm robot forward. All it takes is a single motor to spin the thing, and since it's so simple, you can crank it up to 5 cm/s (which is seriously quick for a robot like this). Perhaps the biggest advantage is efficiency. With a small onboard battery, these kinds of robots can climb vertically for hundreds of meters.

The robots were developed at the Medical Robots Lab at the Technion Israel Institute of Technology by David Zarrouk, Oshri Ifergan, Yossi Baruch, and Moshe Shoham. Look for roboworms to eventually show up in applications including maintenance of small pipes and medical procedures in biological vessels.



KIROBO IN SPACE

A small Japanese humanoid robot named Kirobo is bound for the International Space Station, where it will join the crew as a "communications robot." The Japan Aerospace Exploration Agency and Dentsu, Inc., created the Kibo Robot Project, based on a commercially available robot known as Robi. Kibo's design was created by Tomotaka Takahashi of Robo Garage. Toyota worked on the project too, providing natural language support for the bot. Apparently the "communication" the robot will be in charge of is speaking tweets sent from Earth to Japanese astronaut Koichi Wakata. Two identical robots have been made: Kirobo, who will go into space; and Mirata, who will remain on Earth for PR and educational appearances.



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COMBAT ZONE

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BUILD REPORT:

The Quest for a Different Kind of Flipper: Inspiration and Early Attempts

● by Zac O'Donnell

I have been building fighting robots for several years, and starting in 2009 I managed to build a 12 pound robot named Scurrie that won several competitions in a row. After some time, I was also successful with a 30 pound shell spinner named Tetanus.

While the success of these two robots was long sought and hard won, I found myself craving a more creative challenge.

In my search for a design that was clearly different from other robots, I found a video of a robot named Warrior SKF from Team Whyachi (teamwhyachi.com) that used a powerful ring spinner combined with a clever trigger mechanism to create a very potent flipper — all in the same 220 pound machine.

One thing I found so impressive about the robot was its ability to harness the power in the spinning weapon and transfer it into the opponent

without tearing itself apart. From my experience with my own shell spinner, I knew that just building the spinning portion in a reliable way was not a trivial task, so then seeing that someone had found a way to harness that power and control a flipping arm with it inspired me.

I had found my new challenge: Build a spinner-powered flipping robot.

Team Whyachi had access to funding and manufacturing resources well beyond mine, so for my robot I decided to abandon using the spinner itself as a secondary weapon and just focus on the flipping mechanism.

In 2010, I decided to try to build my robot in the three pound class which was a much better fit for my tools and abilities than the 220 pound class from which I drew some of my inspiration.

Unfortunately, this initial version of the robot (which was

named Eclipso) struggled to make weight and faced serious reliability problems in the trigger mechanism. I decided to use it as a learning experience and planned to try a different approach the following year.

My target event for the second attempt was the July 2011 PA Bot Blast in Bloomsburg, Pennsylvania. I dubbed the new version Recipso as a redo on the original, and decided to try building for the newly supported six pound weight class. I hoped that the extra weight would allow for a heavier and more reliable trigger assembly, so I decided to set about designing one that would work.

The project started like most of my others — in Alibre Design, the 3D CAD package I use to make sure everything will fit and that the robot will be underweight. You can see a complete render of the bot in **Figure 1**. I decided to try to build a four-bar linkage for the flipping mechanism because it fit better with translating the rotational motion of the flywheel into the semi-linear motion of the flipping arm.

It also made the robot look radically different than most flipping robots which was one of the original design goals.

There was a 340 pound robot named Ziggy with a pneumatically powered four-bar flipper that served as partial inspiration for the design, but much like Warrior SKF, Ziggy was the first robot I ever saw to attempt a four-bar linkage in a flipper.

After I had the whole robot designed on the computer, I printed the 2D layout of it out at full scale and taped it down to a piece of garolite. I then used a razor blade to cut out the critical areas of the paper drawing, so I could mark the plate to help with alignment later.

After marking the center of

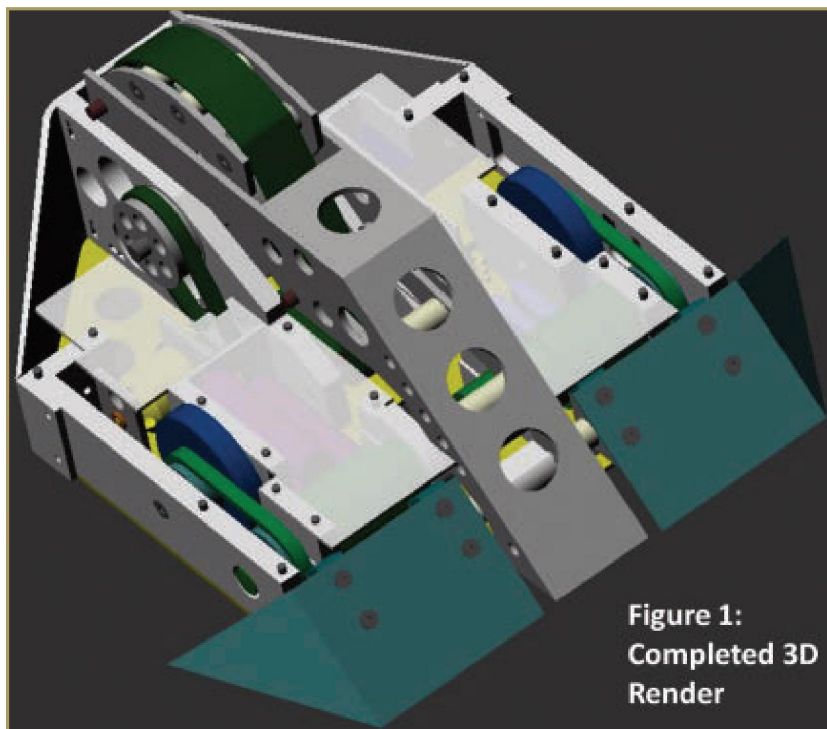


Figure 1:
Completed 3D
Render

each hole, I removed the paper and drilled all of the mounting and weight reduction holes before finally cutting out the wheels and perimeter with a jigsaw.

After that, it was time to cut and drill all of the frame pieces from .375" thick UHMW. The frame

structure on this robot was a scaled down version of the frame that was so successful in Scurrie.

To build it, I bought UHMW bar stock, cut it to the right length with a jigsaw, and then drilled holes all the way through the baseplate and the frame so a bolt

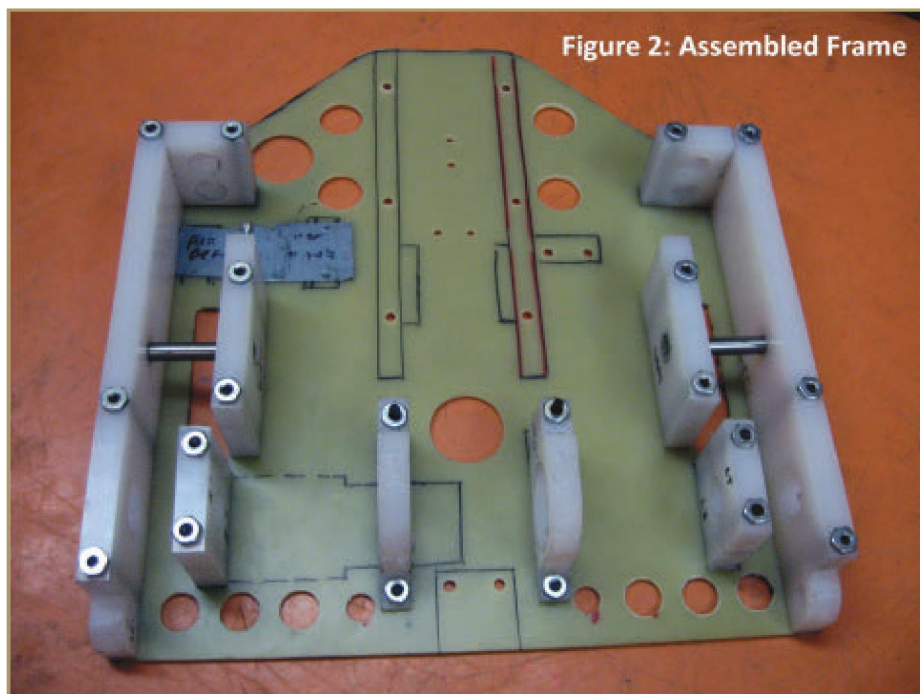


Figure 2: Assembled Frame

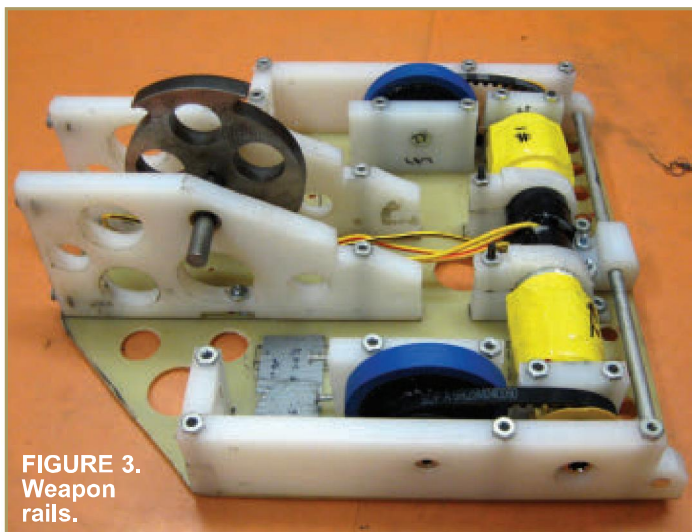


FIGURE 3.
Weapon
rails.



FIGURE 4. Flywheel and steel ring.

could pass through the entire assembly and keep it stiff. This way, there were no threaded holes to strip at the competition and it made a pretty sturdy shock resistant frame. You can see the completed layout without the weapon assembly in **Figure 2**.

So far, the build had been much like any other fighting robot build but now it was time to do the part that made this machine unique. It started with the main plastic rails that held the entire weapon assembly.

These attempted to keep the flywheel, trigger mechanism, and all supporting components aligned and contained throughout the fight. These rails also provided a mounting point for the rear armor bubble as it swooped around the back of the bot.

After the weapon rails were

mounted, I made up a keyed shaft to support and drive the flywheel, and added the drive motors and wheels to the robot, as well (**Figure 3**).

In the middle of the robot, you can see the part that was responsible for storing the energy for the flipper. I have been calling it a flywheel but it is really a custom-cut asymmetric blade designed to provide as much bite as possible at high RPMs.

This is critical for this design because the trigger depends on hooking a steel ring over the flywheel (**Figure 4**) while it is rotating extremely fast, so if there were two teeth opposite each other on the flywheel the trigger would have to go twice as fast

for a successful engagement.

The steel ring was attached to a polyester strap (**Figure 5**), which was then tied to the flipping arm itself. A small electric solenoid was used to move the steel ring into the path of the spinning flywheel when I wanted to engage the weapon.

I chose this approach over a servo because the solenoid could move the steel ring much faster than a servo could, which would again improve the likelihood of a solid engagement.

Once the solenoid lifted the steel ring into the flywheel, the momentum of the flywheel pulled the ring across the edge of the flywheel, and the polyester strap



FIGURE 5. Steel ring and strap.

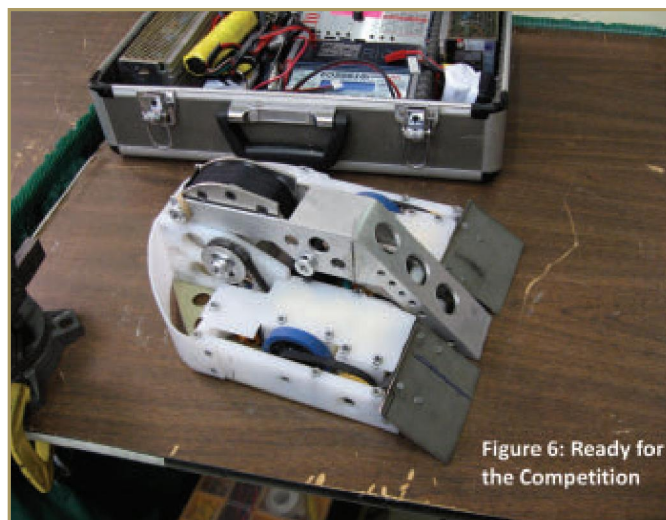


Figure 6: Ready for
the Competition

and flipper arm went along for the ride.

After I completed the flywheel and trigger assembly, I formed the flipper arm out of a piece of aluminum channel and installed the rest of the wiring and components. Other than the trigger solenoid, there were not any special electronics in this machine so the final wiring went quickly.

After that, all I had to add was the back armor and wedges and the robot was ready for the competition (**Figure 6**).

As it turned out, the flywheel did not store enough energy to really throw a six pound opponent, and the trigger mechanism jammed after each time it was fired.

I also had problems at the last minute with the weapon controller that made it so I could not drive and spin the weapon at the same time.

I did get one opportunity at the competition where my opponent was stuck on the wedge which allowed me to turn off the drive motors and spin the flywheel all the way up to get one flip in. The other robot did flip over and Reclipso got its first and only win.

Despite the problems I had, the other builders at the competition voted for Reclipso to receive the Coolest Robot award, making the entire endeavor a success. You can see that event report in the October 2011 issue of *SERVO*.

The design achieved the goal of building something different, interesting, and challenging but it did not prove to be as reliable or powerful as I wanted.

Still, it was an improvement over the original prototype, and it showed that the concept was possible.

I resolved to try again with a different trigger mechanism in another build, but you'll have to wait for another issue to see how the quest continued. **SV**



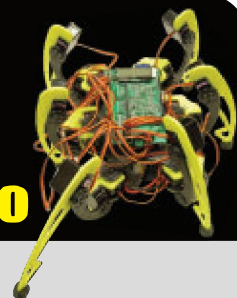
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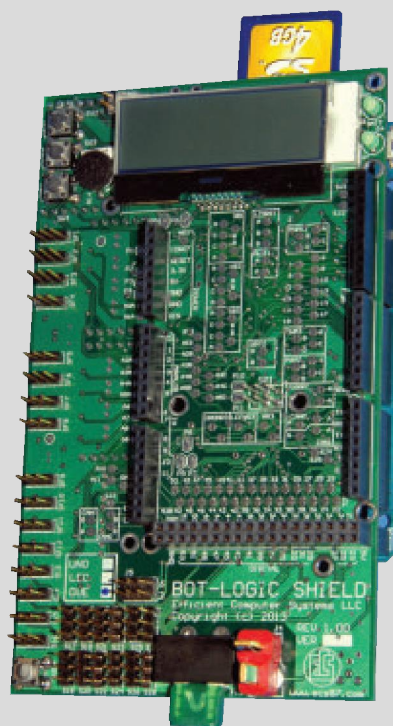
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Then and Now — A Decade Later With Christian Carlberg

● by Kevin M. Berry



FIGURE 1.
Minion-Carlberg.

Last year, the Combat Zone published a series of articles covering the history of the sport by recovering the undocumented, nearly lost information about each of our sport's major events — past and present.

Now, 10 years after the demise of major television

coverage, we tracked down some of the most famous names from that era to gain their perspective on what some see as “the glory days”

of the sport. Our first victim is competitor and host of “The Builder’s Corner” from the BattleBots™ series on Comedy Central network.

CZ: Hey, Christian. It’s been a decade since the “glory days” of televised Robot Combat. BattleBots and the UK Robot Wars were the two shows all robot fighting wannabees — like myself — watched religiously. You worked your way up from competitor to television personality. Could you give SERVO readers a short version of how you moved from the pits to the camera?

Christian: Well, frankly, it is a very common story in business. I got an alternate offer. The producers of “Robotica” asked me to come in for a test video of me interviewing competitors in the pits. They really liked my questions and style, and wanted me for their show. I spoke to the producers (not the owners — there is an important distinction here) of BattleBots and they offered me a Builder’s Corner. To be honest, I liked the idea of interviewing competitors in Robotica better, but I did not want to leave BattleBots.

CZ: Most of Combat Zone’s readers came into the sport (like myself) at small, backyard, or school events. Some have been to medium sized ones, still, of course, not televised. What were the later BattleBots events like with all the hype, advertising,

television, personalities, and actual fighting?

Christian: For me, it was a reunion of friends, people I had known for years since Robot Wars at Fort Mason Center in San Francisco, CA. There were a few newcomers. Then, right around season 3, the newcomers outnumbered the first wave. It was crazy how many people were coming into the sport, and extremely flattering for me to have someone tell me that they read my online instructions to build their robot. (Editor’s note: I built MY first bot based on his “cool robots” site!)

CZ: Was it a huge disappointment to you when the show was cancelled and the sport slipped back into smaller and smaller events?

Christian: Yes and no. Yes, because I had put so much into it to turn my hobby into a career. And no, because when your hobby turns into a career, you don’t find it as fun. As soon as it was over, I stepped back, started a family, and picked up other hobbies.

CZ: Tell us your favorite story about the fabled sportsmanship competitors show each other in this sport?

Christian: This is going to be self-serving, but I kinda like my match-up with Warhead. Warhead was a brutally effective 220 lb mass-spinner with incredible style, built by a legendary UK team. They were tearing up their competition and my robot, OverKill, was next on their list. However, they had repairs to make before our fight and needed a new hobby servo. I gladly gave them one of mine — no hesitation. (Another Editor’s note: I have seen this same selfless generosity dozens of times in combat robotics. I’ve seen people cutting parts out of their wrecked bot — still in the arena — to get the bot that beat them ready for the next fight. I’ve seen superstars — like Christian and many others we’ll interview — helping stone cold newbies get their machines ready. We can be proud of the standards of sportsmanship we’ve upheld over the last 15 years. End of sermon. KB)

CZ: Come on. Who won?

Christian: I won that fight. Just about everyone figured I would have my ass handed to me, but I

knew paper covers rock. I guess part of me wanted to show that my robot could and would win.

CZ: Coolest fight?

Christian: One of my most fun lightweight fights was Toe-Crusher against Tony Buchignani's/Dan Danknick's Evil Fish Tank because both robots were extremely fast, very well made, and well driven. We were flying all over the arena and when a floor saw blade occasionally tagged us, it would kick our robot across the box. I won that fight too, and the only reason I remember it was because it was a two-for-one; I got Dan and Tony (both friends of mine) in one fight.

CZ: So, it's been 10 years. What's been up with you since then? What's your latest passion?

Christian: I still freelance building robots for people and one of my side projects is building an open source Arduino style programmable flashlight called the FLEX at www.hexbright.com.

CZ: Hold it. Really? A software controlled flashlight? I mean, I'm no Luddite, but isn't that just majorly nerd-level gold plating? Why do you need that?

Christian: Why do I need a programmable light? What can I do with that? I don't know yet. And that's the point. I want to release the HexBright Flex into the wild and let the community develop original source code. I want to see how brilliant (pun intended) people can be and supply an outlet (hexbright.com) where folks can swap and share lighting code. I'm not fundraising just to make creative lights, I want to build online creativity.

CZ: Well, I never saw fighting robots coming 12 years back. Maybe in 2025 you can say "I told you so!"

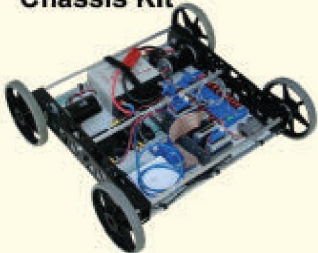


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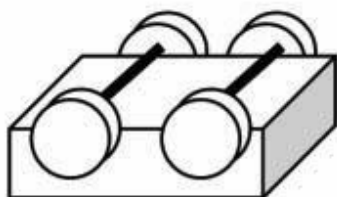
Christian: You're certainly welcome. **SV**

Melty Brains

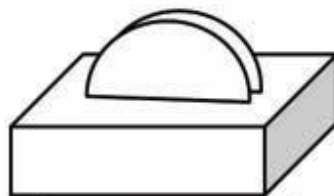
Bad Design Choices

by Kevin Berry

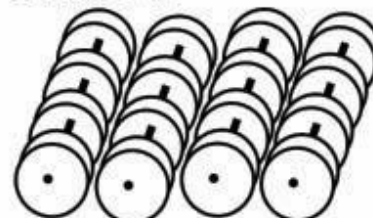
Tired of losing wheels to undercutters, Silly McSilly Pants embarks on a series of progressively worse design choices ...



Won't Roll!



Won't Steer!



Let's see 'em eat all THESE!

EVENT REPORT:

Motorama 2013

● by Pete Smith

Just this February, the Northeast Robotics Club (www.nerc.us) hosted the 11th annual combat event at the 2013 Motorama motorsports extravaganza and custom car show (www.motoramaevents.com) in Harrisburg, PA.

Ninety-eight bots registered this year, and entered in a total of six weight classes from the 250 g Fairyweights to the 30 lb Featherweights and Sportsmen. Eighty-four passed through safety checks and actually competed. This figure was down somewhat from last year — mainly due to a reduction in the number of Fairyweights, plus there was no high school 15 lb class this year. One big growth area was in Beetleweights, where 29 took part this year over only 21 in 2012. The slight drop in numbers was — if anything — more than

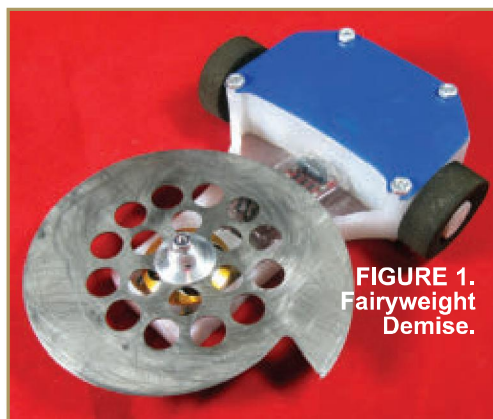


FIGURE 1.
Fairyweight
Demise.

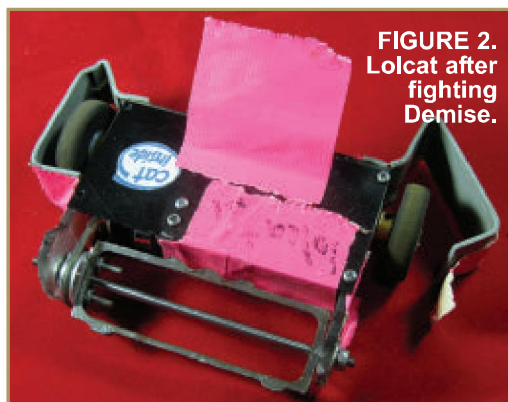


FIGURE 2.
Lolcat after
fighting
Demise.

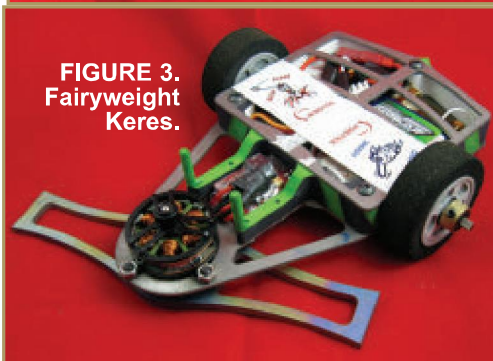


FIGURE 3.
Fairyweight
Keres.



FIGURE 4.
Antweight
Poco
Tambor.

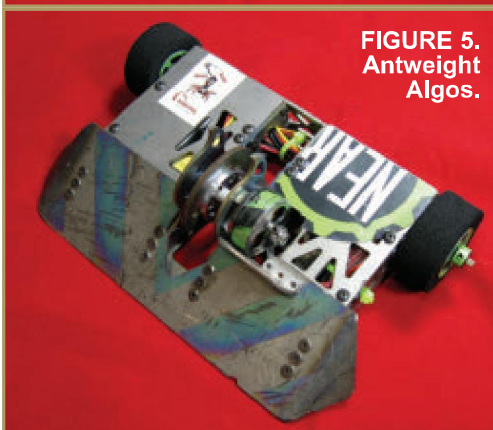


FIGURE 5.
Antweight
Algos.

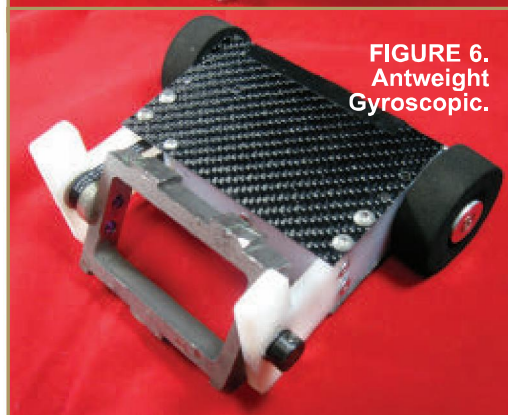


FIGURE 6.
Antweight
Gyroscopic.

TABLE 1 - MOTORAMA 2013 WINNERS.

	<u>FAIRY</u>	<u>ANT</u>	<u>BEETLE</u>	<u>HOBBY</u>	<u>FEATHER</u>	<u>SPORTSMEN</u>
1st:	Demise	Low Blow	Mondo Bizarro	Cataclysm	Tetanus	Upheaval
2nd:	Lolcat	Cannon	Coercion	Zandor	Pinball	Tyrant
3rd:	Keres	Algos	Grande Tambor	Attrition	Hot Fuzz	Nyx

offset by an improvement in quality.

The two smallest weight classes competed on Friday before the main show opened, since they lack the spectacle of the heavier bots. Friday morning is typically spent setting up the small arena, the tables in the pits, etc., and the fights get started in the early afternoon.

Five 250 g Fairyweights and 18 1 lb Antweights took part.

The Fairyweights went round robin, i.e., each bot fought every other one. Two bots dominated: the horizontal spinner, Demise (**Figure 1**) and Lolcat with its horizontal beater bar. The winner was decided when Demise ripped open Lolcat's wheel guard and knocked out the drive on that side (**Figure 2**). Demise went 5-0 to take first place, with Lolcat and Keres (**Figure 3**) taking second and third places.

The Antweight contest was double elimination — each bot had to lose twice to be eliminated.

There were strong performances from Poco Tambor (**Figure 4**), Algos (**Figure 5**), and Gyroscopic (**Figure 6**), but it came down in the end to who was tougher — Cannon (**Figure 7**) or Low Blow (**Figure 8**). Cannon won the first round, but Low Blow came back through the loser's brackets to beat Cannon twice in the finals, wrecking it in the process (**Figure 9**) to take a well deserved first place. While this competition was taking place, NERC members and volunteers assembled the main 16 x 16 arena (**Figure 10**), and carried out the safety checks on any of the larger bots that had arrived.

The main event for the Beetleweight and heavier classes of bots got underway on Saturday. The morning saw many more teams arrive and the pits fill up. There was the usual rush as teams completed their bots and got them through safety.

FIGURE 7.
Antweight
Cannon.

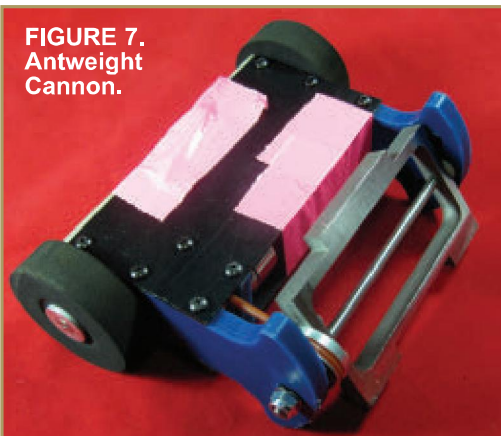


FIGURE 9. Cannon after fighting Low Blow.

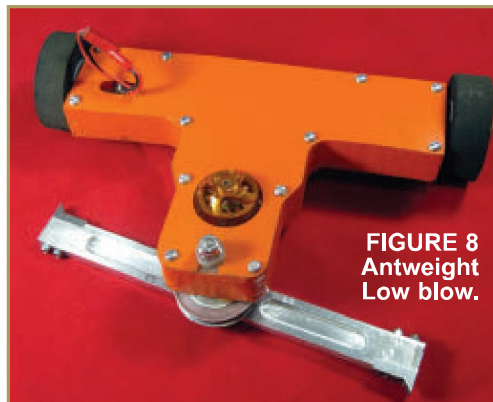
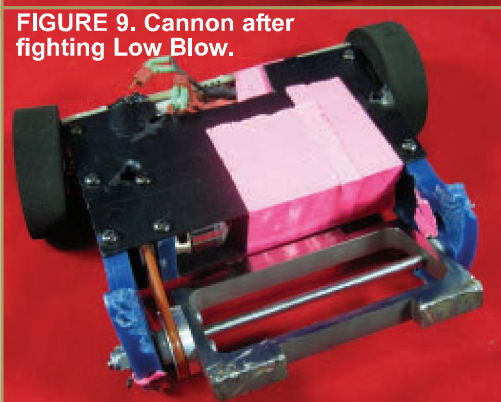


FIGURE 8
Antweight
Low blow.



FIGURE 10. Building the big arena.



FIGURE 11. Busy bleachers.

The fights got underway around noon, and continued with only a short break for lunch until early evening, then restarted the next morning with the last finals held around 4 pm on Sunday. There were big crowds throughout Saturday (**Figure 11**) and steady attendance on Sunday.

Twenty-nine bots fought it out in the 3 lb Beetleweight class. Newcomers like the horizontal blade spinner Coercion (**Figure 12**), Weta Kit Mondo Bizarro



FIGURE 12. Beetleweight Coercion.



FIGURE 13. Beetleweight Mondo Bizarro.

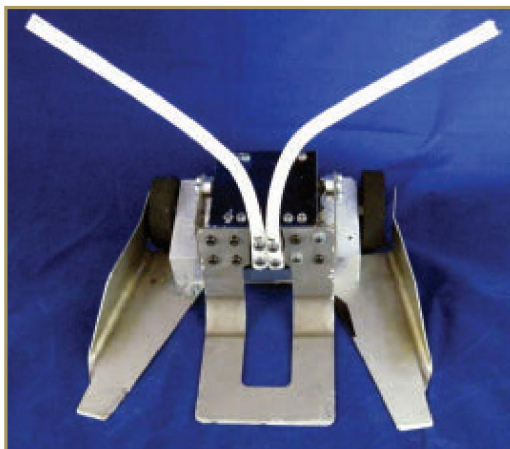


FIGURE 14. Beetleweight The Revenge of Doctor Super Brain.

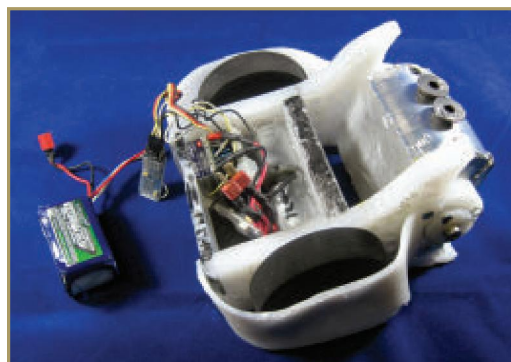


FIGURE 15. Beetleweight Grande Tambor.

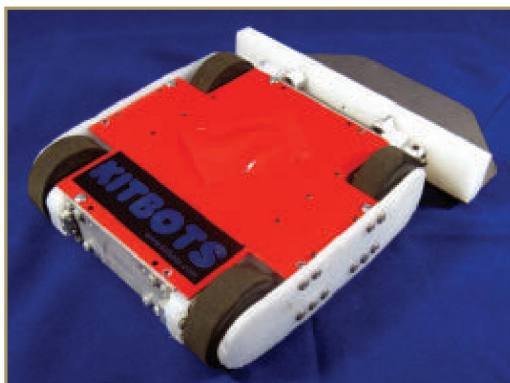


FIGURE 16. Beetleweight Trilobite.

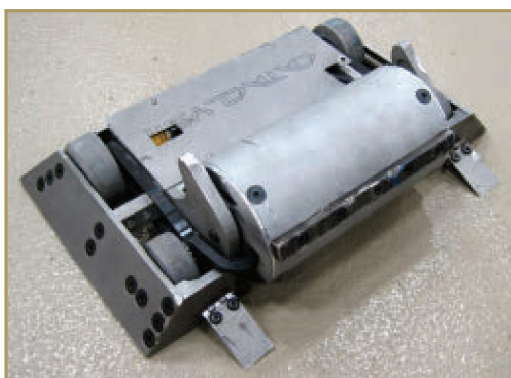


FIGURE 17. Hobbyweight Cataclysm.



FIGURE 18. Hobbyweight Apollyon.

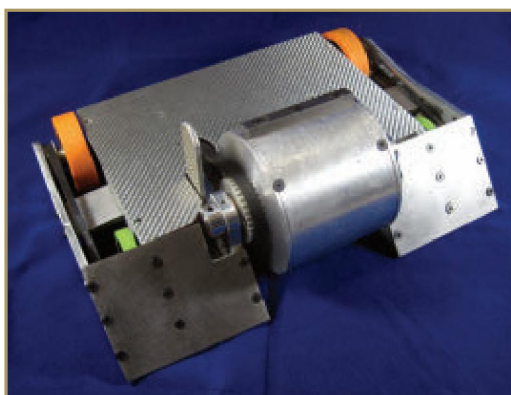


FIGURE 19. Hobbyweight Upchuck.

(Figure 13), and Hammerbot Mangle-Gore fought hard with veterans like last year's champion, The Revenge of Doctor Super Brain (Figure 14), uber drum bot Grande Tambor (Figure 15), and wedges Trilobite (Figure 16) and Shame Spiral, but it was the newcomers Coercion and Mondo Bizarro that fought it out in the finals, with Mondo Bizarro winning in a quick knock-out.

The 15 12 lb Hobbyweights this year included the 2011 champion Cataclysm (Figure 17) and 2012 champion Apollyon (Figure 18), horizontal blade spinner Fiasco, drumbots Attrition, Upchuck (Figure 19), Zandor, and newcomer Ripto Ultimate (Figure 20), plus two shell spinners Sonic the Hedgehog and Anonymous. There were many good fights like Ripto Ultimate versus Flatline (Figure 21), but as in 2011, Cataclysm simply dominated, running the brackets and then ending with a convincing win over Zandor in the finals (Figure 22).

Upheaval once again dominated the Sportsman class, manhandling K-onstant (Figure 23), but it was two new bots that attracted the most interest from the builders: Überclocker, a flipper/lifter (Figure 24), and kinetic energy

flipper Jack Reacher (**Figure 25**). The former could lift and carry just about any of the other bots that it could get a grip on — even the large and heavy Such and Such (**Figure 26**). It further entertained the crowd in the Sportmans Rumble by picking up a robot and using it as a club to beat another bot!

Jack Reacher used the energy built up in a spinning drum to power a flipper through an ingenious mechanism (I'm trying to persuade the builder to write an article about it for *SERVO*). This was its first ever competition and it worked remarkably well, apart from a tendency to flip itself upside down at the same time it threw its opponent (**Figure 27**).

The 30 lb Featherweights were the most powerful class at Motorama. There was a new horizontal spinner Deep Impact (**Figure 28**) which looked promising but had the bad luck to draw last year's champion full body spinner Tetanus in its first match. The result was it was torn apart (**Figure 29**). Its main problem was a slow spinup and a weak spot where the side armor was secured on one side. General Disarray (**Figure 30**) was back with new heavy rubber armor designed to fend off Tetanus, but its weapon did not seem to be working well, and it was knocked out before ever meeting its main rival from last year. Tough wedge Pinball and Tetanus fought it out for first place (**Figure 31**), with Tetanus first in the semis, leaving Pinball a smoking wreck (**Figure 32**), and repeating that in the finals to retain the championship for another year.

The event finished on time and the prizes supplied by sponsors Dimension Engineering, Fingertech Robotics, Kitbots, Holmes Hobbies, ServoCity, Team Whyachi, and The Robot Marketplace were awarded by three of the "Miss Motorama" contestants. Special thanks are due to Roy Hellen (in the armor) and Jon Durand (**Figure 33**) for their excellent commentary throughout the main event.

Many of the competitors stayed on to help with dismantling and loading up the big and small arenas,

FIGURE 20.
Hobbyweight
Ripto Ultimate.

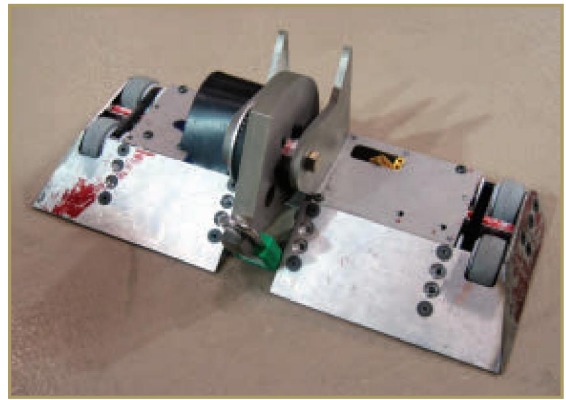


FIGURE 21.
Ripto Ultimate
versus Flatline.



FIGURE 22.
Cataclysm
versus Zandor.





FIGURE 23. Sportsman Upheaval versus K-onstant.

plus all the other tidying up required in the pits area.

The traditional post Motorama dinner was held at the Texas Roadhouse and, as usual, a good time was had by all. NERCs next big event is likely to be at the Franklin Institute in Philadelphia this Fall. **SV**

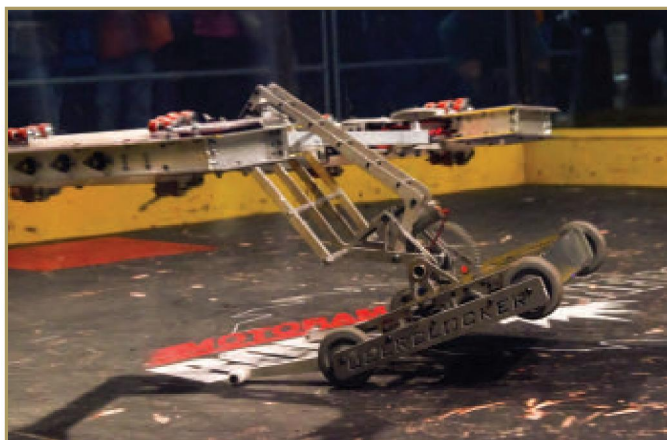


FIGURE 26. Uberclocker versus Such and Such.



FIGURE 27. Jack Reacher versus K-onstant.

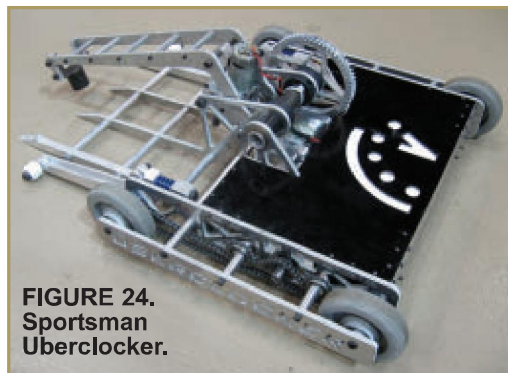


FIGURE 24. Sportsman Uberclocker.

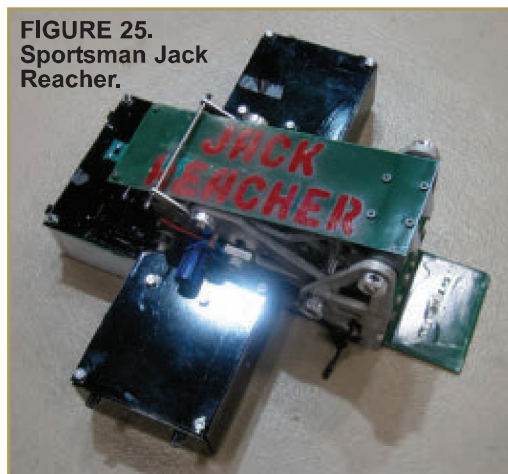


FIGURE 25. Sportsman Jack Reacher.

Photos by Pete Smith and Brian Benson (www.bensonpv.com). Many of the fights mentioned above can be found on YouTube by searching on the bot's name and "Motorama 2013."



FIGURE 28. Featherweight Deep Impact.

FIGURE 29.
Featherweight
Deep Impact
after fighting
Tetanus.

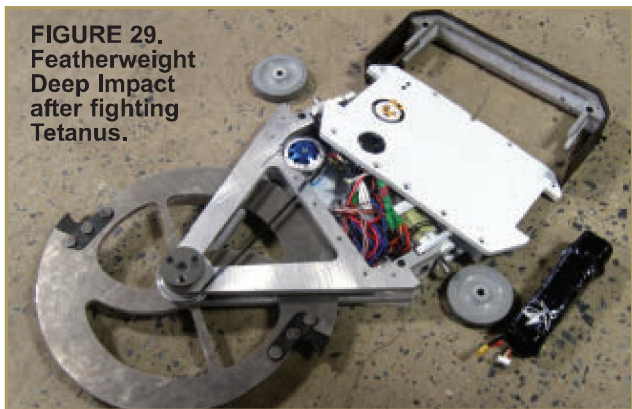


FIGURE 30.
Featherweight
General
Disarray.

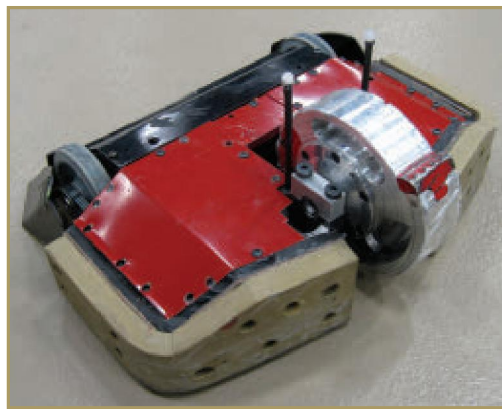


FIGURE 31.
Tetanus versus
Pinball.



FIGURE 32. Pinball
wrecked and
smoking.



FIGURE 33.
Roy and
Jon.



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Enter the MATRIX:

A Robust New Build System for FTC and Beyond

by Greg Intermaggio

www.servomagazine.com/index.php?/magazine/article/may2013_Intermaggio

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MATRIX Robotics is a brand new metal robotics system now available for the FIRST Tech Challenge (FTC), as well as for hobby and educational use. The system is exceptionally intuitive, and allows for users of LEGO MINDSTORMS to seamlessly transfer both their building and programming skills to a sturdier and more scalable medium. I recently had the opportunity to experiment with MATRIX and design my own model, DasBot. The following is my in-depth review and opinions of the system, but first, let's get some context.

MATRIX Robotics

MATRIX Base Set (US \$499.00)

MATRIX Robotics was founded in 2011 by a group of experienced robotics enthusiasts with ambitions to provide a more flexible, higher quality, 3D metal build system. The MATRIX Robotics system provides a lower cost alternative to TETRIX for FIRST Tech Challenge (FTC) competitors, which is especially pronounced in international markets where the cost of a simple TETRIX starter kit can reach well over \$1,000. While its success in competition with VEX and TETRIX remains to be seen (kits are just now starting to ship), MATRIX has a lot going for it.



THE COMPETITION

VEX Robotics

VEX Dual Control Starter Kit (US \$799.99)

The first mainstream metal robotics system, VEX was initially introduced by RadioShack, and shortly thereafter was acquired by Innovation First International. VEX is no longer allowed in FTC and has their own proprietary VEX Robotics Competition, or VRC. The competition kits consist of the controllers, motors, sensors, software, and a variety of structural components; it's an all-inclusive kit for a reasonable \$799.99 in the US. VEX tried to bring metal robotics to the average consumer by making it affordable, but in the process, sacrificed some quality and flexibility. VEX kits have come a long way since their acquisition in 2006, but some of the problems that the kit was born with still remain.

PROS:

- Affordable
- Lightweight

CONS:

- Notoriously Flimsy
- Limited Build Options
- Proprietary Control System



TETRIX

TETRIX Education Base Set (US \$599.95)

TETRIX was Pitsco's MINDSTORMS-compatible answer to VEX. The system is sturdy, perhaps even over-engineered. The parts are of exceptional quality, and the eight-hole circular connection system tries to offer more flexible designs than VEX. Pitsco knew their competition well, and hit VEX where it hurt, but TETRIX was not without its own shortcomings. The circular connection system is great in theory, but when developing robots that incorporate anything but right angles, it is very difficult to predict what will fit. This often leads to a "hack at it till it fits" design mentality. Due to the heavy weight of the individual parts, TETRIX bots for FTC often exceed 50 pounds, compared to VEX and MATRIX bots which easily cut that number in half. The starter kit costs \$599.95 in the US, but does not include a complete control system (MINDSTORMS or remote purchased separately), and has fewer total parts than the comparable VEX and MATRIX kits.

PROS:

- Exceptionally Sturdy
- MINDSTORMS-Compatible

CONS:

- Expensive
- Heavy
- Confusing Build System Geometry



About the Bot

DasBot is the first major MATRIX model I've designed. The bot is currently remote controlled via Bluetooth from a second NXT, and the control software was programmed entirely in NXT-G. I designed DasBot to showcase the coolest aspects of the MATRIX Robotics system. The bot can move forward, backward, and steer proportionally with a gyro sensor; its claw can grab/lift/lower/release a small MATRIX pylon. For more on MATRIX including DasBot building and programming instructions, visit <http://matrixrobotics.com>.

The Grid

Perhaps the most innovative aspect of the MATRIX is its joiner system. Joiners are attached on the inside of L-beams and C-channels, allowing for a seamless extension. This gives builders the ability to align their entire robots onto a single grid. The joiners come in straight for extending beams and channels (**Figure 1**); 2D for joining two beams or channels at a single right angle (**Figure 2**); and 3D for joining three beams or channels in a corner (**Figure 3**). On a practical level, this means that your designs will be significantly simpler and more symmetrical, using fewer pieces as spacers.

MATRIX is based on an 8 mm grid just like LEGO, making the kits exceptionally geometrically compatible. This grid, combined with the joiner system, helps to solve the problem of grid misalignment that can face robot builders when attempting to design original robots with other kits.

FIGURE 1. Straight joiner.



FIGURE 2. 2D joiner.



FIGURE 3. 3D joiner.



DasBot Application

In designing DasBot, I took advantage of almost every joiner MATRIX has to offer. I used the XL-joiners to connect the main parts of the chassis, taking advantage of their structural integrity to extend the lower beams of DasBot's chassis while simultaneously joining it to a vertical strut (**Figure 4**).

Standard sized joiners were used to attach smaller components like the claw (**Figure 5**). I also used the standard straight joiners to support the D-shafts that held the bot's wheels.

This allowed me to keep the wheels and D-shafts inside the chassis (**Figure 6**).



FIGURE 6. Wheel well close-up.

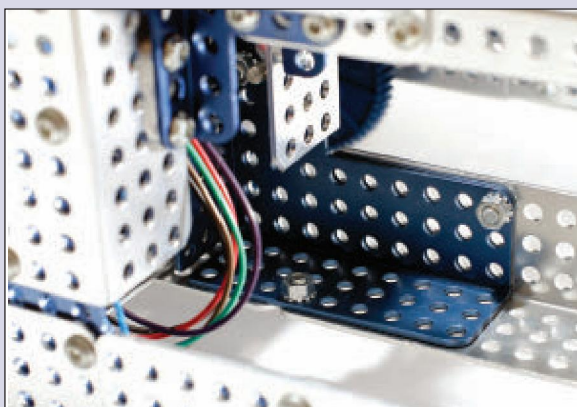


FIGURE 4. Inside DasBot: The center vertical struts are attached via the same L-shaped XL joiner that extends the bottom of the chassis.

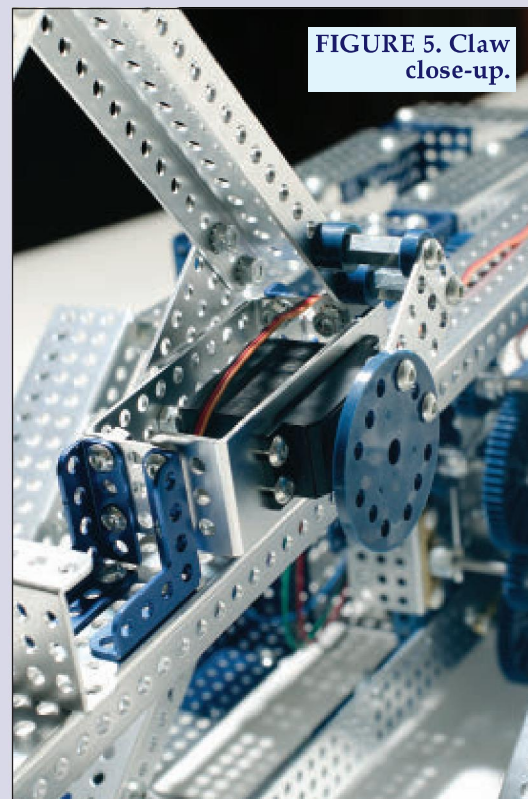


FIGURE 5. Claw close-up.

Rapid-Prototyping Flexibility

Arguably, the most common reason builders stray back to LEGO from metal build systems today is the lack of rapid-prototyping options. It simply takes more time and more effort to screw together each piece, compared to simply snapping them together. MATRIX approaches this problem with their unique Quick Connector system. The Quick Connectors are two-part plastic pieces: a small pin and a sheath for the pin to slide into. Pushing the pin all the way into the sheath opens the end, locking the connector into place on a beam, plate, L-bracket, or any other holed MATRIX piece. Quick Connectors provide a great alternative to screws and nuts for prototyping, and for permanently connecting medium to low impact points on your bot (**Figure 7**).

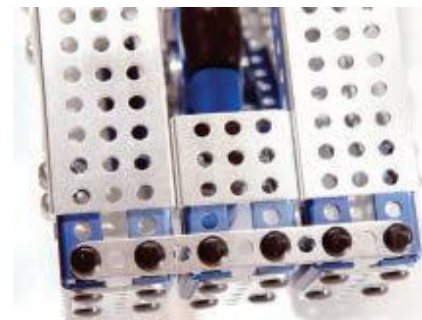


FIGURE 7. Quick Connectors can be used to permanently attach low impact points.



FIGURES 8A-8C. Quick Connectors come in three flavors.

The Quick Connectors come in three flavors: short, medium, and long. Short connectors are the perfect length to connect two pieces of metal; medium connectors fit three; and long connectors fit a MATRIX beam plus a LEGO beam. I also found that for temporary prototyping purposes, you can get away with using a larger than necessary Quick Connector which is useful for connecting four pieces of metal together; refer to **Figures 8A, 8B, and 8C**.

DasBot Application

I do a lot of iterating in designing my models, and DasBot was no exception. The generally large size of the MATRIX models and L-shaped beams tend to make getting your tools and/or fingers to the center of a complex model for adding and removing pieces relatively easy. There were more than a few times during DasBot's design where the Quick Connectors significantly simplified the design process. The single biggest advantage of the MATRIX Quick Connector system is the ability to snap in from only one side of an assembly, whereas a screw and nut combo requires being able to reach both sides. This saved me a lot of grief in prototyping, especially with the compact parts of DasBot like the wheel assemblies (**Figure 9**).

The Quick Connectors also look cool, and I found myself inclined to use them in the front bumpers of DasBot not only due to the speed I could assemble them in (each bumper took all of about 10 seconds to assemble), but for the aesthetic value, as well. Like little black rivets, the Quick Connectors stand out on the silver background of the beams and gusset plates, making for a very striking visual contrast.



FIGURE 9. Under the front wheels.

MATRIX Geometry

The best robots are simple and purpose-built, and require a build system that is simultaneously robust, flexible, and predictable — a very tall order. LEGO Technic and MINDSTORMS have long been lauded as the gold standard

of small-scale robotics build systems, but the fact of the matter is they're toys — the average student/hobbyist graduates from LEGO to a metal platform, and based on Technic's intuitive build system, it should be no surprise that where TETRIS borrows design elements from Lynxmotion's (also cool) Servo Erector Set (**Figure 10**), MATRIX aims to



FIGURE 10. A C-Channel from Lynxmotion's Servo Erector Set.



FIGURE 11. MATRIX and LEGO geometry are almost identical.

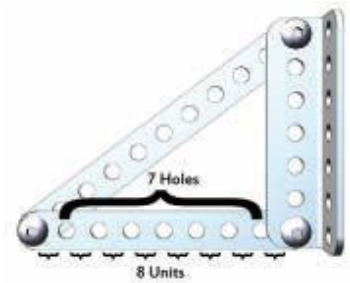


FIGURE 12. This 4-8-10 triangle has seven holes between its bottom vertices, but eight units.

bring the competition to the next level by very closely replicating the geometry of LEGO Technic and its adherence to an 8 mm pitch hole pattern.(Figure 11).

Like LEGO Technic, MATRIX is designed such that any multiple of a 3-4-5 triangle (in MATRIX units/LEGO studs) will align perfectly with the grid. To create a 3-4-5 triangle with MATRIX, multiply three, four, and five by a common coefficient, then subtract one from each of the products. The three resulting numbers represent how many holes you should have between each vertex of your triangle — not including the vertices themselves (Figure 12).

Suddenly, it becomes very easy and predictable to incorporate angles into your designs, both for structural integrity and for aesthetic purposes. This convenience is amplified by the fact that MATRIX and LEGO structures line up perfectly, so even your angular designs can integrate seamlessly across platforms.

Why Subtract One?

When we multiply three, four, and five by a common coefficient, the result is the number of MATRIX units that should be between each vertex of the triangle. The problem with that calculation is that it means we're not counting the holes themselves in the MATRIX pieces, but instead, we're counting the spaces between the holes. By subtracting one from our result, we can count the holes instead of the units.

Also helpful is the myriad of shapes and sizes of MATRIX beams and plates which allow great flexibility in design, without overwhelming you with too many choices. L-beams and C-channels are best used for creating a sturdy frame, with flat beams and gusset plates filling the roles of secondary reinforcements, low impact structural elements, and alternative spacers — often a better choice than the included plastic washers.

perfectly, the ramps are actually quite well-reinforced, making for a design that's not just talk.

More Scalable System

One of the biggest shortcomings of the VEX and TETRIX platforms, in my opinion, is their lack of scalability. Their beams and C-channels have only one width, and all robots must be structured around that. Larger VEX models tend to sway due to their thinner beams, and it is very difficult to build a compact TETRIX model due to their exceptionally large C-channels. (Figure 13.)



FIGURE 13. It's difficult to design compact TETRIX bots.

MATRIX attempts to solve the scalability problem by offering two widths of L-beams and connectors: standard and XL. Standard beams and connectors are compact and sturdy for their size. They can be used to create small to medium models with ease, much like the beams of VEX. XL parts, on the other hand, are the equivalent of the behemoth TETRIX C-channels, and are also similar to TETRIX in their impressive weight capacity. XL MATRIX parts are sold separately and are best used for larger models like those built for FTC.

Gears That Fit

If there's a single element of the MATRIX Robotics system that I am most impressed with, it's gotta be the gears. The lightweight (but sturdy) polycarbonate makes

DasBot Application

I wanted to take advantage of the ease of creating angles while staying on the grid with MATRIX, and so the entire front portion of DasBot is sloped, creating a very appealing aesthetic look. Because the geometry lines up

SOURCES

Information about
MATRIX Robotics
<http://matrixrobotics.com>

To find MATRIX distributors
[http://matrixrobotics.com/
products/distributors](http://matrixrobotics.com/products/distributors)

FIRST Tech Challenge
[www.usfirst.org/robotics
programs/ftc](http://www.usfirst.org/robotics/programs/ftc)

DasBot Application

Most of the primary structural components of DasBot utilize XL beams and connectors to create an exceptionally sturdy frame. Because of the width of the XL beams, I was able to easily mount components on the “inside” of the beams, making for a robot that is large, but also quite efficient and compact (**Figure 14**). The drive trains and front wheels are all mounted internally, as well as several cross-beams for support.



FIGURE 14. DasBot packs a lot of components into a little space.

Wheel Options

MATRIX currently gives you three options for wheels in two diameters: 96 mm with tread, 48 mm plastic, and 96 mm omni-wheels. The 96 mm wheels with treads can be securely attached to each other via standoffs, which is especially helpful for larger models that require more support and traction. The 48 mm plastic wheels are great both for making free-spinning casters, and also for use on lighter robots with tank steering as fixed casters.

The most noteworthy wheels are, of course, the MATRIX omni-wheels (**Figure 15**) — both for their utility and their ingenuity. The omni-wheels have two configurations: single and tandem. Single omni-wheels function identically to VEX and TETRIX counterparts, but when you attach them in tandem, their genius shines. The alternating rubber sections create an almost perfect outer radius for the wheels, thus making a much smoother ride for your robot.



FIGURE 15. MATRIX omni-wheels, configured in tandem.

DasBot Application

While DasBot was too compact to utilize the tandem configuration of the omni-wheels, I did use single ones for the front wheels, allowing the bot to turn easily despite its heavy weight. I immediately fell in love with the flexibility of the configuration system, since it gave me the choice between a very compact setup and a slightly smoother ride.

them impressively strong for their weight. Due to their size combined with the geometry of the MATRIX grid, you'll be pleased to find just how many options you have for creating a perfect gear mesh. Additionally, MATRIX gears interface beautifully with LEGO gears, which only makes working between the

two kits easier. Perhaps the coolest thing about the gears is their form factor. While they are two units wide including the collar, their shape allows a compound gear train to be built inside a space of just three units of width which is incredibly helpful when you need a gearbox in a small space (**Figure 16**).



FIGURE 16. A three-unit-wide compound gear train.

DasBot Application

The bot relies on a well-integrated gear train for the drive motors and the lifter. The drive motors require gears to fit comfortably inside the frame, while providing a small increase in torque. The lifter gear train is a bit more complex, and actually results in a ~15.12:1 gear ratio, providing a significant increase to torque.

Noteworthy is that DasBot's complex lifter gear train doesn't fit within the three-unit width (**Figure 17**). This is because the lifter gear trains use all three sizes of MATRIX gears; a three-unit wide gear train must only use two sizes. Your keen eye may also notice that there are actually two gear trains for the lifter — one

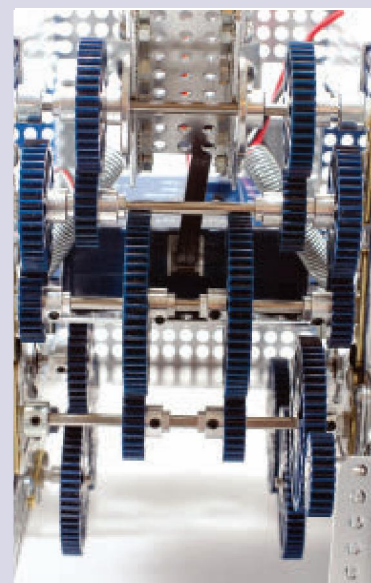


FIGURE 17. DasBot's lifter gear train.

ending on either side of the arm. This tandem gear train disperses the stress on each D-shaft, reducing twisting and wear.

How Can MATRIX Do Better?

MATRIX models will tend to fit somewhere in between VEX and TETRIX in terms of sturdiness. Much like both of the other platforms, a well-designed MATRIX robot of any size will be plenty sturdy, while a poorly designed one will sway. The flat beams in particular could stand to be manufactured from a higher quality of aluminum to avoid accidental bending.

At the 2012 FTC World Championship in St. Louis, teams from all over the world got their first glimpse of MATRIX Robotics, with some fantastic models on display at their booth. There was a lot of excitement about the kit, and more than a few people expressed their interest in the universal joints and belt drives incorporated into some of the models on display.

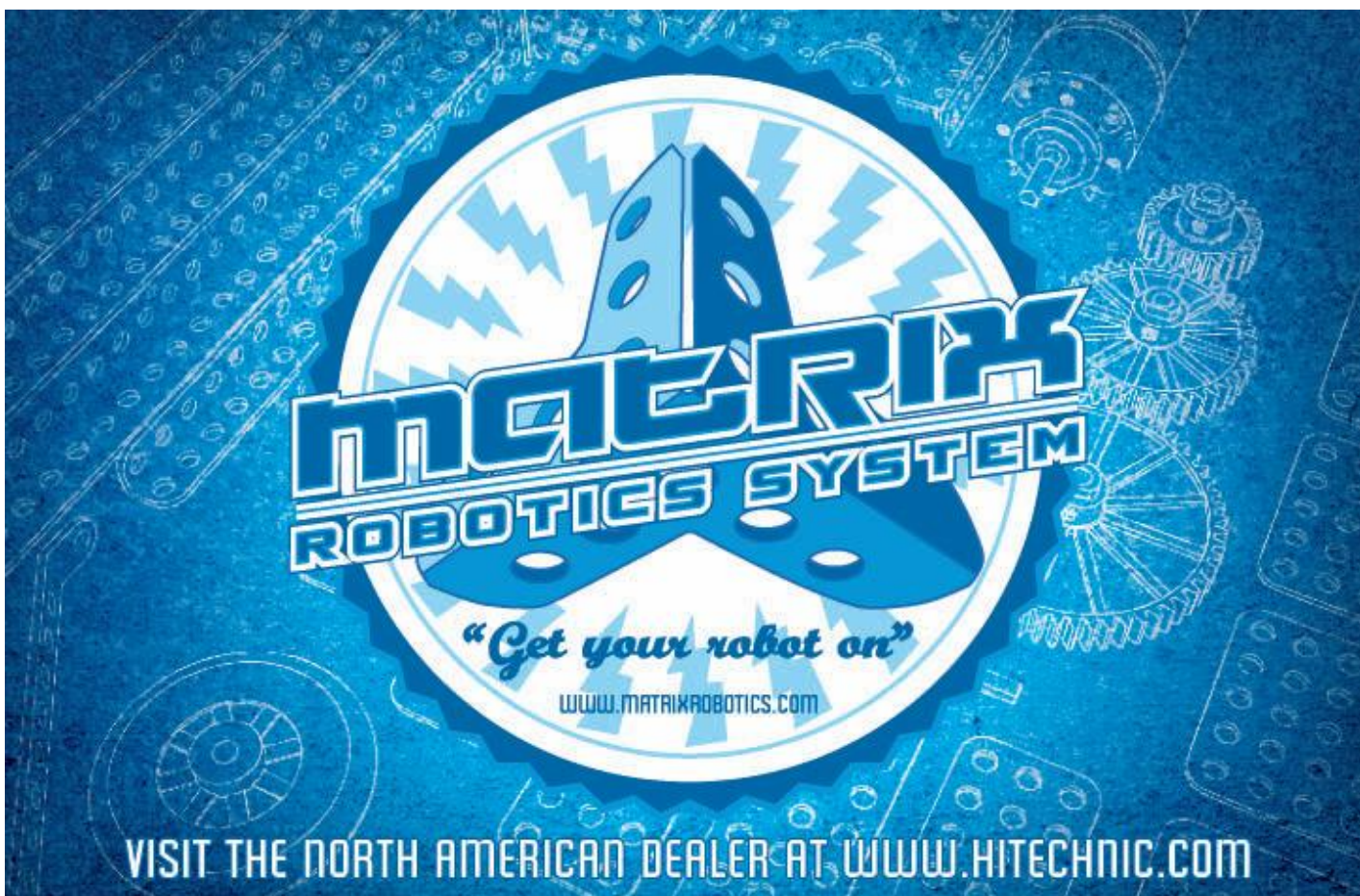
These awesome parts are unfortunately not currently available from MATRIX, but the team is hard at work finalizing the designs for distribution. While it's a bit disappointing that they aren't here now, I share the anticipation of what's to come with many MATRIX enthusiasts.

Because they're a small operation, there's a definitive personal touch from MATRIX support with exceptionally fast responses to questions and great customer service. However, the downside of their small size is that it takes a while for some of their innovations to reach the market. I look forward to seeing the company grow and reduce their turnaround time on new products.

This is the first time in quite a while that I've been this genuinely excited about a new robotics platform (the last time was the release of the NXT), and so I look forward to seeing how the system matures. I'm especially excited about the impact it will have on the growth of the FIRST Tech Challenge, given the low price point of the kit. I hope we see the same pace of growth in FTC as we are in FIRST LEGO League which had over 20 thousand teams compete last season alone, compared to 2,500 FTC teams.

All said and done, MATRIX Robotics is a spectacular new kit. Everyone I've spoken to who's had the opportunity to work with the kit has been very excited about it, and in particular, the simplicity and flexibility of the system.

At \$500 USD for the base kit including over 750 pieces, it is actually cheaper per piece than LEGO MINDSTORMS NXT (though you'll need to buy a controller separately). That is very impressive for a metal system. If you have an opportunity, take a few minutes to experiment with MATRIX. You'll like what you see. **SV**



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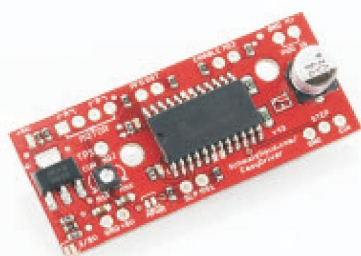
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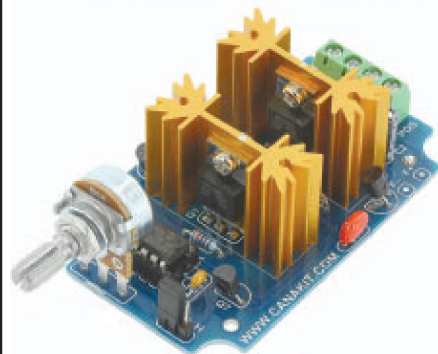
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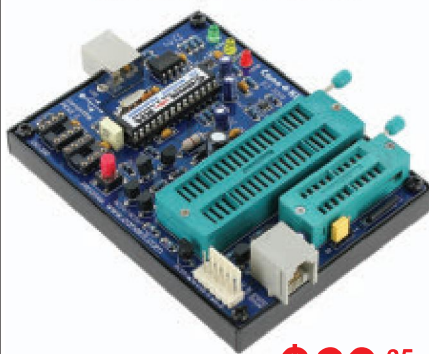
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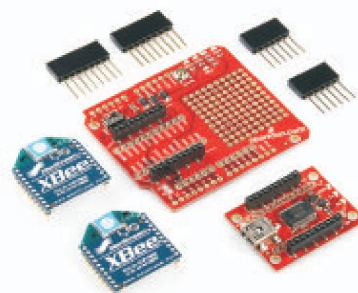
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Creating a MiniBot



Building robots with a great finished look does not need to be difficult or expensive. This article will cover how to construct a good looking robot on a budget. When starting out, it is best to build a robot on an open chassis. This allows easy access for experimenting and changes, while learning how to control servos, connect sensors, and add or remove options. Once you get a good handle on how things fit together, you may want to build something a bit more permanent that people will immediately recognize as a robot. If this is where you are heading, then you may want to take the next step and build something like these MiniBots!

Birth of the MiniBot

My youngest son asked me to build up another custom robot. I enjoy working on all sorts of robot projects and didn't need much encouragement to start another one. For years, people have been using trash cans as bodies for robots. They work out great for providing a protective cover for all the electronics and can also serve as the chassis.

We had gone to the local Target and while browsing the aisles, I noticed a small trash can that looked ideal as the basis for a new robot. It was a 1.32 gal (5L) swing can that seemed to be Target's own ROOM ESSENTIALS brand. The base is about 8-1/2" tall and 7-7/16" in diameter. With the top installed, the overall height is 12".

I saw they carried these small trash cans in both black and a frosted white/clear version. At under \$8 a piece, I bought one of each to use as the base/frame for the new robot. Since I now had two different ones (funny how one project easily turns into two!), I decided that I would build one using a Parallax P8X32A Propeller QuickStart board as the brain and the other would be based on the popular Arduino Duemilanove/UNO board using an the Atmel ATMEGA328 processor.

To keep the costs down, I wanted to use many of the inexpensive robot sensors that have been showing up on sites like **propellerpowered.com** and on eBay. In particular are the HC-S04 sonar rangefinders, PIR sensors, digital voltmeters, and small 9g servos that are right around \$3 each. There is also a relatively new text-to-speech chip called the RoboVoice that has been on sale for about \$17 from the **speechchips.com** website.

NOTE: Since this trash can had a top cover with the swing lid, I added a servo to control the movement of the lid similar to what another prolific robot builder (Steve Norris) had done on his BAXTER robot. His robot is a much larger scale build than presented here, but both are based on swing trash cans and use a servo to move the lid.

His robot is a great example on where you can go when you want to step up to even larger robots. Check out the links in the **sidebar** to get more details on his robot.



The finished robot next to a bare trash can.

Preparing the Drive System in the Base

The MiniBot uses a pair of standard size continuous rotation hobby servos for the main drive system. These are the easiest way to get a small robot mobile. I've used them before on my SpindleBots which I wrote about back in the April 2012 issue of *SERVO Magazine*.

On all of these robots, I modified standard servos for continuous rotation. The method I prefer is to bring the adjustment potentiometer outside of the servo. With the potentiometer exposed, the servo can be calibrated and adjusted at any time to set the center/neutral point.

If you want to go that route, you can get details from my SpindleBot article or from numerous places on the Web.



PIR sensors.

There are some links in the **sidebar** to get you started. A quick Internet search should turn up detailed instructions to modify your particular servo.

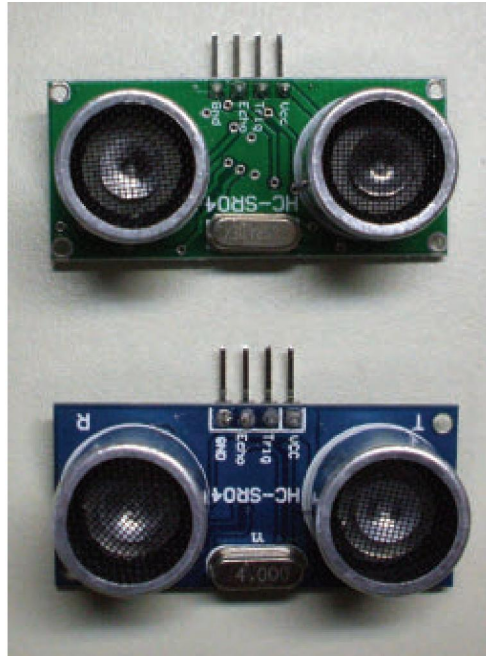
NOTE: I think the best option for most people building this robot is to use a pair of servos that are already set up for continuous rotation. The one I would suggest is the Parallax 900-00008 continuous rotation servo. This has an opening on the side so you can adjust the neutral position of the servo as needed. By putting a pair of access holes in the back of the finished robot near the bottom, these can be easily re-adjusted at any time using a long thin screwdriver.

For the wheels, this robot uses standard servo-based robot wheels common on small Sumo and Boe-Bot robots. The ones in this article came from 1SORC, but the new Parallax 721-00018 (blue) or 721-00019 (red) wheels are a great option since they have a silicon tire molded directly onto the wheel, so you no longer need to wrap the wheels in a rubber band for traction.

These wheels are a breeze to install since all you need to do is remove the servo horn, press the wheel on the shaft in its place, and secure it with the original screw.

With the wheels attached, the base is marked for the rectangular openings to allow each of the main drive wheels to protrude through the bottom of the base. Working with plastic is relatively easy and a sharp X-Acto or other hobby knife will do the job.

There are many different techniques for cutting plastic, but I usually make a light cut on the outline and then go



Two variations of the HC-SR04 sonar modules.

over it several more times, cutting each pass a little deeper. It can sometimes help to drill a small hole at each of the four corners. Then, the unwanted plastic should pop out of the opening.

The servo motors are then mounted to the base with double-stick tape. Just set them lightly in place at first so you can unstick them and reposition them if needed. You want to make sure the wheels are straight and that the centers of the axles are aligned with the center of the robot.

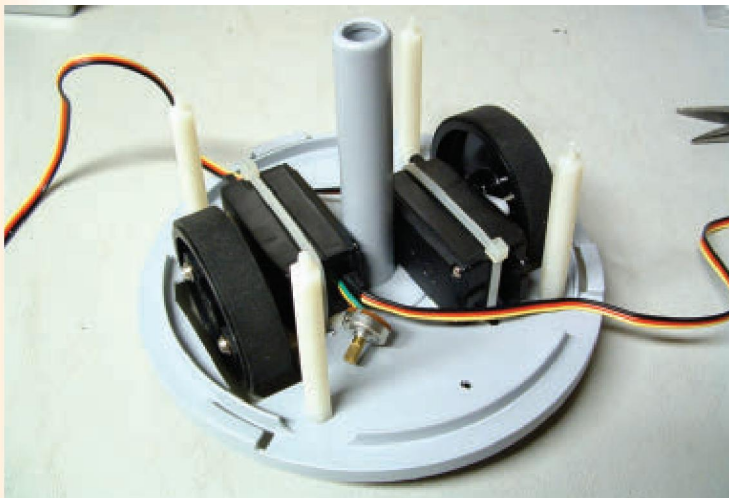
After verifying everything is in the proper place, you can press down tightly to set the adhesive on the tape. To make sure they won't move or break free, add a cable tie around each servo to keep them securely in place. Just drill a hole in front of and behind the servo body so you can route the cable tie through the base.

If you are using the Parallax servo that has the adjustment hole, make sure

you locate the cable tie between that hole and the tabs near the top of the servo which are normally used for mounting. Otherwise, you may block access to the adjustment opening.

To complete the base, just add a pair of small furniture glides on the underside of the base using #4 hardware. These are located at the front and rear to help keep the robot level. A small spacer (1/4" or so) will probably be needed to position the glides closer to the ground. Be sure to leave some clearance between the glides and the ground or the robot will end up getting stuck as it moves.

NOTE: One other servo modification is to open up one servo, remove the motor, and reverse the polarity so it will run in the opposite direction. This mod isn't as common any



Assembly of the SpindleBot base.



Bottom of the SpindleBot base.

more, but can make the programming slightly easier for people since the pulse width you send to them means the same for forward and reverse on both servos. Otherwise, the pulse widths would mean the opposite from side to side if one motor isn't reversed.

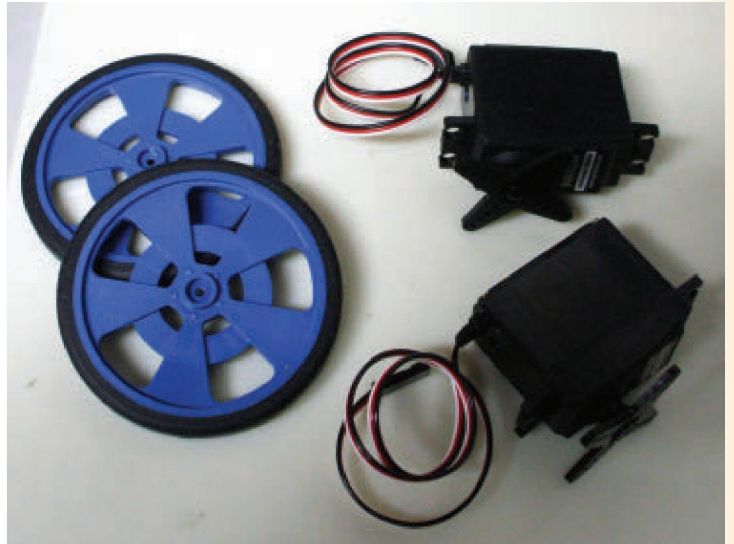
Powering the MiniBot

I wanted to make sure there was plenty of power available to keep the MiniBot rolling for a long time. A good choice seemed to be a 7.2V 4,200 mAh NiMH flat battery pack from All-Battery. This battery pack was made from a set of six Sub-C cells. It is mounted vertically inside the robot, attached to the back of the can with two squares of double-sided tape. Two holes are drilled through the back on each side of the pack near the middle, and a cable tie is installed around the battery and through the back.

To make sure the battery pack wasn't sitting directly on top of the screw holding the glide on the base, I installed a pair of stick-on rubber feet to support the battery and provide clearance. With the extra weight toward the back, the robot favors the rear slider so it normally ends up touching the ground when moving.

A power switch and voltmeter were added to wrap up the power section. The power switch is just a mini toggle switch located on the back of the robot about 1.25" from the top edge of the body, centered over the battery. It breaks the circuit on the positive lead coming from the battery pack. In order to keep tabs on the battery voltage, I picked up a small DC 3.3V-17V blue LED voltage monitor. It has three seven-segment displays.

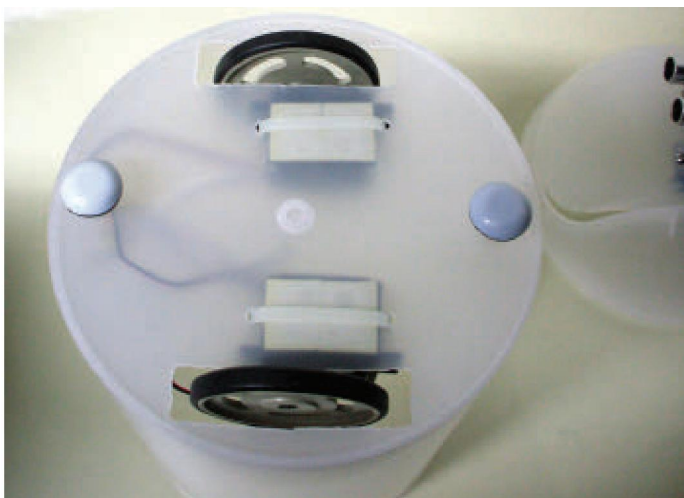
There are a couple different variations on eBay that I have seen for sale. Make sure to look for the two-wire versions since they can be powered directly from the battery you want to monitor. Avoid the three-wire versions since you would have to provide an additional power source to power the meter itself.



Main drive servos and wheels.



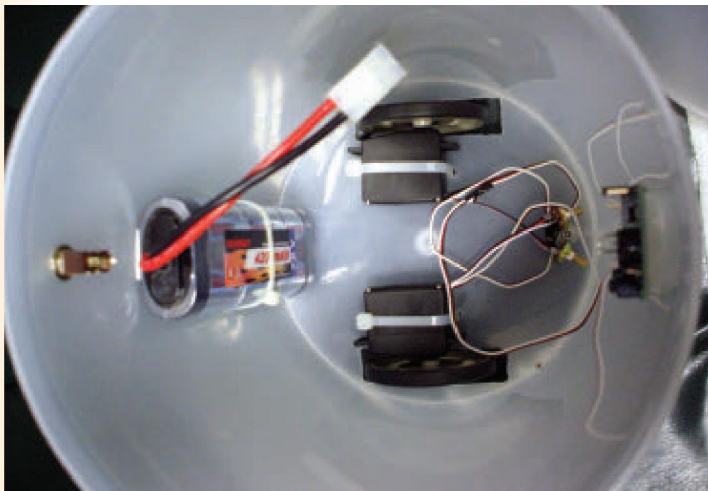
Sliders used at front and rear of base.



Position of the drive wheels and glides on base.



Mounting of the servos and glides.



Mounting of the battery, power switch, and PIR sensor.



The finished back panel of the MiniBot (voltmeter, power switch, USB port, and volume control).

It is connected to the output of the power switch, so it displays the battery voltage whenever the robot is on. The meter is mounted on the back of the robot next to the power switch. On the robot with the black trash can body, just cut out a rectangular opening so you can slide the voltmeter through and secure it with a drop of glue.

On the frosted white/clear version, you can set the meter inside the can and secure it with a pair of screws. This provides a great looking display since the readings will show right through the body.

With the meter installed, it is easy to tell how the battery is doing at all times, and it provides a cool display. It shows the load on the battery increase whenever the servos are moving and when other circuits are active that draw a noticeable amount of current.

These meters are so inexpensive now, I install them on all my projects.

Mounting Sensors and Devices on the Body

Now that the base has the main drive and power system all installed, it is time to move on to some sensors and miscellaneous items. Since we may want to have a MiniBot perform guard duty, one of the first sensors to add is a PIR sensor. There are some inexpensive adjustable ones available from Propeller Powered. Another good option is the newer Parallax PIR module which will light up when it detects motion. This shows whenever it detects something, so you can tell when it is triggered. The sensor is mounted directly on the front of the robot from the inside. I drilled a small pilot hole about 2" down from the rim. Then, I drilled a hole large enough so the domed lens can just fit through using a stepped drill (Unibit) which is an ideal tool for this. It can make large holes in plastic without cracking it. Once the hole is in place, I use a bit of adhesive (GOOP) to hold the sensor there.

Since these robots use a speech chip, they need a speaker installed. The best location for the speaker seemed to be on the front of the robot about 4.5" down from the rim under the PIR module. I drilled a large hole and added a perforated cover so the sound would project through. A series of smaller holes drilled into the front would work just as well. If you go that route, try to align them in a good looking pattern. The speaker itself was mounted to the inside of the body directly behind this opening using two screws.

NOTE: When drilling into plastic, you need to be very careful not to crack it. To start, just use a small drill to make a pilot hole. Any drill bit 1/8" or less will do. Then, follow up with a Unibit or stepped drill to enlarge the hole. The stepped drills are much less likely to catch and crack the plastic. If you try using a larger drill bit, it will more often than not break the plastic instead of making a proper hole.

Preparing the Head Assembly

One of the most interesting features of the MiniBot is the automatic control of the swing lid and the panning control of the sonar module on top. Not only can you aim the sonar from side to side, but you can also tilt it up and down to help build up a nice map on what may really be in front of the robot.

Since this is a small robot, we need to use small servos for the task. I used a pair of inexpensive 9 g servos from eBay that were close to \$3 each shipped. Standard sized servos are just too large to fit in the lid.

Getting the servo installed for tilting the swing lid can be tricky and is probably the most difficult part of the build. Start by popping out the swing lid from the top cover. You should then see two thick pins on either side of the top cover. The servo can be mounted on either side, but I

mounted them on the left (as viewed from the back). On the side where the servo will be placed, remove the mounting pin from the top by cutting it flush with the edge of the opening to allow for the servo horn attachment.

On the inside of the lid where the servo will go, cut the locating tab next to the hole on the inside of the lid, flush with the top. The servo will sit inside the lid with the shaft centered in the hole and the servo tightly against the side of the lid. Secure the servo to the lid using a pair of small aluminum L brackets and 4-40 hardware. Since the lid is curved, you will need to bend the L brackets so they are open more than 90 degrees, so the servo body will sit level when mounted.

Using either a servo tester or a small program on your microcontroller, set the servo to its neutral center position and install the straight servo horn so it is directly horizontal. Set the lid back in place on the top, and verify the mounting location of the servo arm. Turn the servo arm to one extreme (either with the tester or manually by hand) and install a small self-tapping screw through the servo arm into the top cover. Move the servo to the other extreme and install a second screw. It is a very tight fit and may be tough to get the screw in place.

You can trim the lid near the servo location to provide clearance and make it easier to get to the servo arm mounting screws. If there isn't enough clearance along the front and rear edges of the lid and it rubs on the top cover, then you may need to sand down the lid until it moves without binding.

After the lid servo is installed, the one for the panning is a breeze. Just locate the exact center of the lid and drill a hole for the servo shaft to come through. Make the hole larger than the shaft since it also needs to clear the servo arm that goes on top. To secure the servo to the lid, I used

Parts List

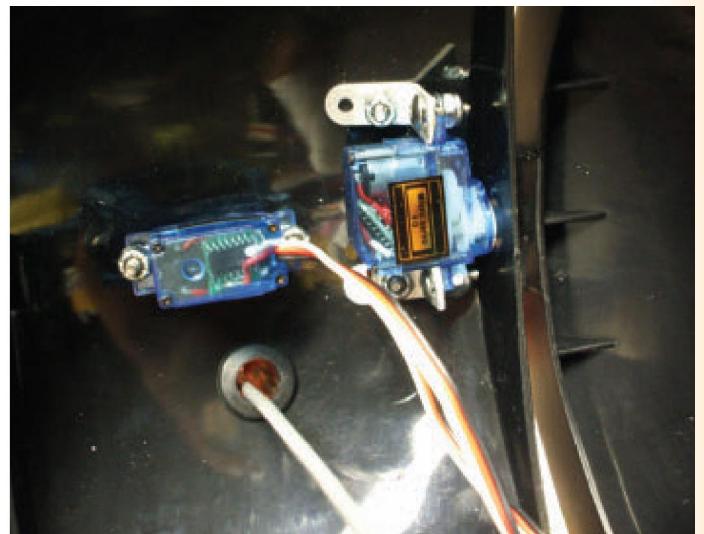
- ROOM ESSENTIALS Swing Can 1.32 Gal (5L) 12" h x 7 7/16" d (Target) Black 490642000382 or Clear 490642000399
- (2) Parallax continuous rotation servos
- (2) Wheels for servo motors (Parallax, 1SORC, etc.)
- (2) Small gliders w/spacers
- (2) 9 G micro servos for sonar pan and lid tilt (metal gear preferred)
- 7.2V 4,200 mAh NiMH six-cell Sub-C battery pack
- NiMH charger
- Controller of your choice (Propeller, Arduino, BASIC Stamp, SX48 OEM, PICAXE, etc.)
- Prototyping board for above controller
- Three- and four-pin SIP headers for connecting cables
- Sonar module (HC-SR04, Parallax PING))) or similar)
- PIR motion detector (Propeller powered)
- Small aluminum L bracket for mounting lid tilt servo and microcontroller board
- RoboVoice chip
- Audio amplifier mono and eight ohm speaker
- Battery voltage monitor (eBay)
- Power switch assembly (RadioShack)
- Sonar mounting bracket (1" aluminum angle)
- Four-pin (four-wire) CD-ROM audio cable for HC-S04 sensor
- Three-pin (three-wire) F/F cable to connect PIR sensor
- Servo extension cables
- USB panel cable w/adaptor (if needed)
- Misc #4 hardware for mounting head servos, speaker, microcontroller board, and glides.
- Double-sided tape for mounting servos and battery pack
- Assorted cable ties to mount servos and battery pack.
- Parallax line sensors (optional for line following)

a pair of long 4-40 screws with nylock nuts. Two holes are drilled in the lid to match the holes on the mounting tabs of the servo.

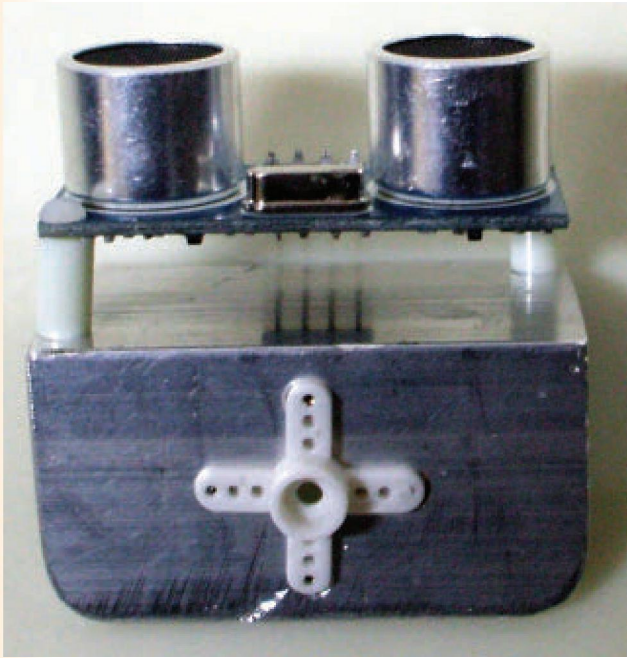
My robots use the HC-SR04 sonar modules. These modules do seem to work well and are very, very cheap which helps for building a robot on a tight budget. The downside is they have a slightly different form factor from



Mounting of the lid servos from the top (see-through view).



Mounting of the lid servos inside.



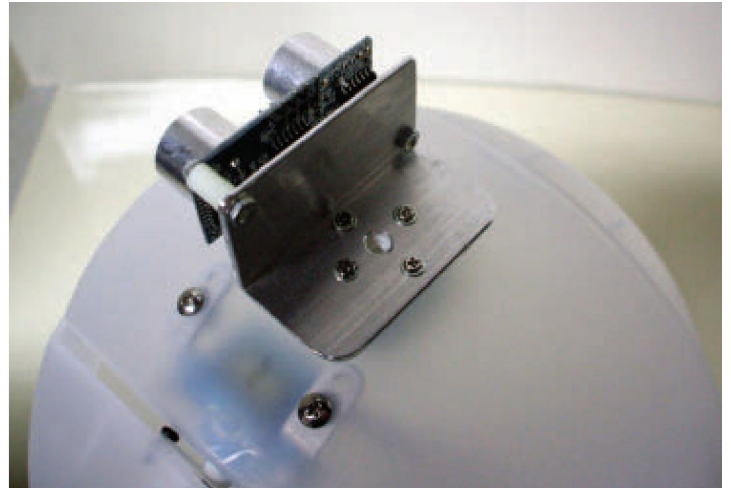
The custom sonar bracket made from aluminum angle.

all the standard sonar modules. The HC-SR04 modules are wider overall, have a wider spacing between the two metal transducers, and also have some of the smallest mounting holes I've ever seen. The most difficult part to deal with is the tiny mounting holes.

There are at least a couple different flavors of the HC-SR04 modules around. Some are green with four mounting holes, and others are blue with two mounting holes. If you are extremely careful, you can usually drill out a couple of the mounting holes to accept a #2 screw. When mounting them, you should add an insulating washer to help protect the components placed right next to the mounting holes. You can't go any larger than #2. Otherwise, you will be breaking through the edge of the PCB (printed circuit board) or knocking off parts. During the build, I actually had a small surface-mount cap come loose on the back of one module. Luckily, I was able to resolder it. Instead of using screws to mount the sensor, you could use some double-sided tape or GOOP to avoid the mounting hole issue.

Since these sensors are too wide to fit the standard sonar brackets, I just made one to fit the module. Just pick up some 1" aluminum angle from your local hardware store and cut a length the size of the sensor or a little longer. On the bottom side, you need to drill a set of five holes to secure the bracket to the servo arm. The four outer holes are smaller and accept the small self-tapping screws that go into the servo arm. The center hole is larger to provide clearance, so you can access the center screw in case you ever need to remove the servo arm to replace the servo.

On the vertical portion facing the front, just drill two more holes for the #2 screws (if you want to use screws to



The finished sonar bracket and sonar mounted on robot.

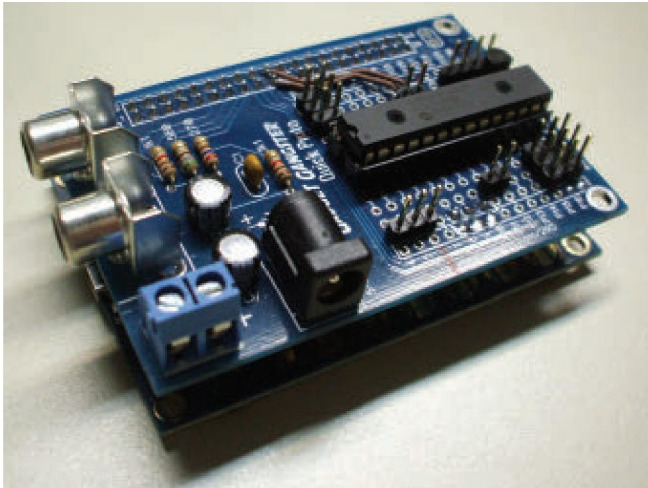
hold in the sensor). If you are going to use tape or glue, then you don't need to make these holes. When mounting the sensor, the four-pin connector is facing up.

In order to get the cable to connect to the sonar module, you can drill a hole on the lid about 1.5" behind the hole where the panning servo comes through. Again, a stepped drill works well for this. I added a rubber grommet to protect the wire going to the sonar, but since the cover is just plastic you should be okay without it. The only other thing that is mounted to the head panel is a small normally open pushbutton switch. This is good for user input. I put this about 1.25" down from the edge of the opening for the lid. You can use just about any style pushbutton switch, or add extra switches if you prefer.

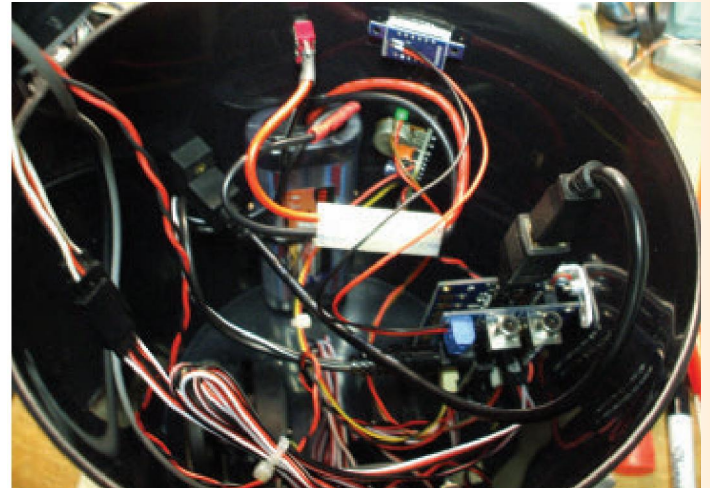
Adding Brains to the Beast

With most of the robot construction complete, it is time to install a brain in our creation! You can really add just about any controller that is your favorite since there is quite a bit of room in these robots. The first robot is based on the Propeller QuickStart #40000 board and can use the #40010 P8X32A expansion board or similar to handle the custom wiring specifically for the robot. The second robot uses an Arduino board with a generic prototyping shield to handle the custom wiring and connections for the robot. Even though there are two different processors, there is a lot in common with the way they are used. They each have the processor, USB interface for programming, etc. Since the processor boards are used as they are and don't need any customizing, they are attached to the body of the robot using a small aluminum bracket. This way, the daughtercard containing all the custom wiring can be unplugged. This helps whenever you want to make changes or add more features later on.

Both processor boards have built-in voltage regulators to drop down the 7.2V battery power for the processor and



The finished QuickStart Brain with expansion board installed.



The finished Propeller QuickStart powered robot.

some of the circuits. These aren't really intended to supply enough current for all the servos. For those, we use an old trick and have a couple of large 1N5401 diodes (in series) to drop the voltage from the battery pack to a safe level for the servo power supply.

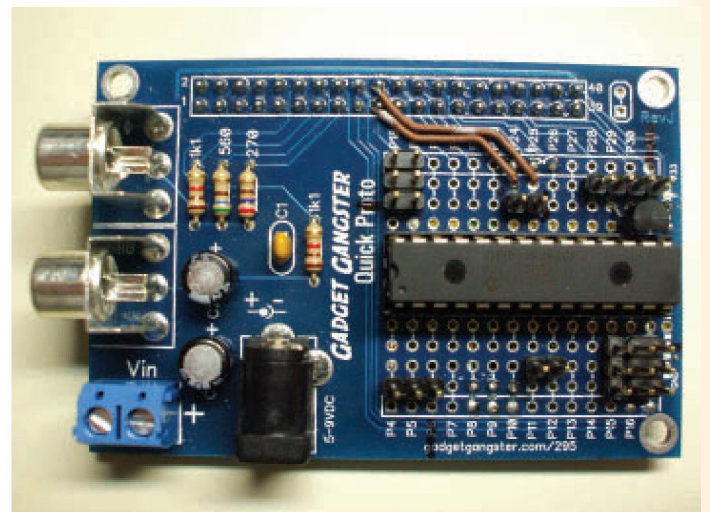
The robot won't need to be opened up just to update the code or install a new program because I added a USB panel mount connector to each of the MiniBots. This goes with the finished look and feel of the robot. The short USB panel mount cable just plugs directly into the Arduino board. For the QuickStart, I also needed a USB to mini USB adapter to make the connection.

Building the Propeller-Based QuickStart Version

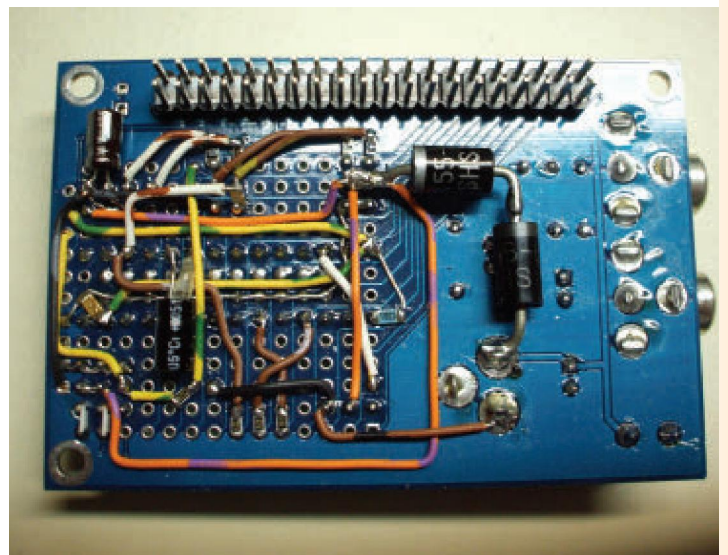
One thing to watch out for when mounting the QuickStart (or any other board) is if the mounting holes are electrically connected to anything or if they are isolated. If you are unsure, you may end up causing a short circuit or ground loops that you never intended. Since I was mounting the board to the plastic body using a small aluminum bracket, I wasn't too concerned about that because the plastic body would act as an insulator.

What I didn't expect was that the one mounting hole I chose near the upper left of the board by the 40-pin connector on the QuickStart would be troublesome. I had pulled out some of my recycled fasteners to mount the board and the screw had a starred lock washer on it.

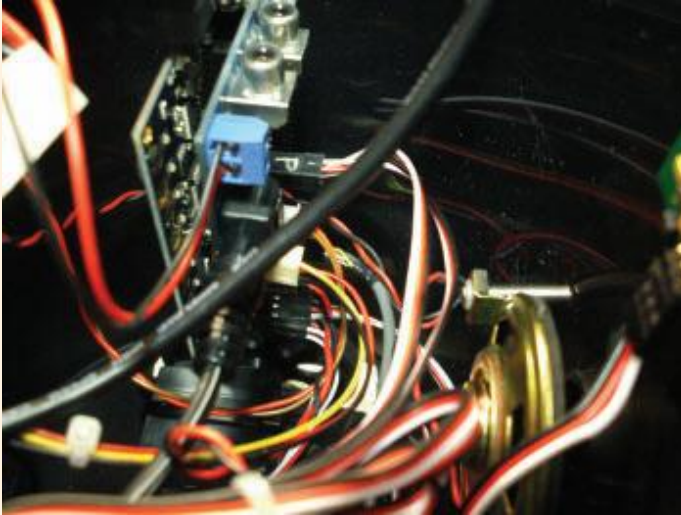
Normally, that would be fine but that mounting hole just happened to have a positive ground plane right around the ground connection of the large pad around the hole. There was hardly any clearance between the two and the lockwasher on the screw caused a short right at that spot. The board had been working flawlessly but didn't do anything once it was mounted in the robot.



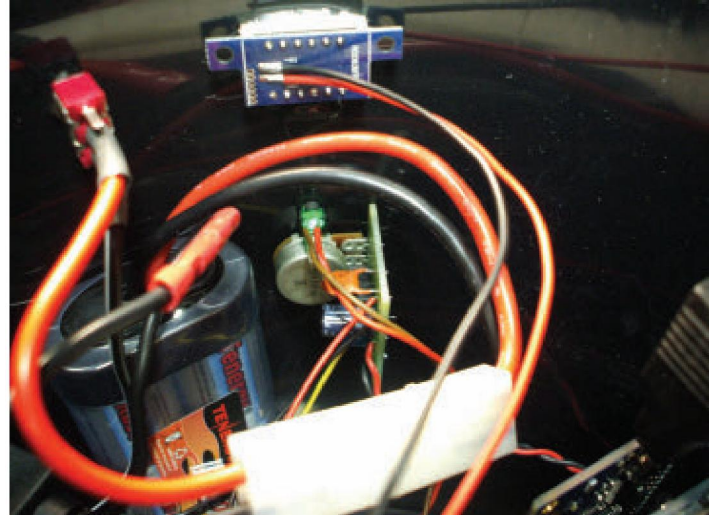
The finished QuickStart expansion board (from top).



The finished QuickStart expansion board (solder side).



The finished wiring for the Propeller QuickStart powered robot.



The audio amp board used on Propeller based MiniBot (speech chip on QS expansion).

Since the only change I made was adding the mounting bracket, it didn't take long to find. The fix was easy. I just installed a different screw and added a small fiber insulating washer to ensure no shorts would develop there later on.

The PIR module and RoboVoice chip can run at the same 3.3V supply as the Propeller chip, so those

connections were simple. When connecting to 5V devices, a small inline resistor of at least 1K ohm on the I/O pin is typically installed between them. Since the HC-SR04 sonar module requires 5V to operate, I added a small 78L05 voltage regulator at the connector for the sonar module. It takes the 7.2V from the battery and provides proper power for the sensor. If you have any questions about your

Website References

Parallax (Continuous rotation servos and robot wheels)
www.parallax.com

Parallax support forum (Propeller QuickStart support)
<http://forums.parallax.com/forum.php>

Propeller Powered (Sonar sensor, PIR sensor)
www.propellerpowered.us

1SORC (More robot wheels in different colors)
www.1sorc.com/product.asp?specific=2033

RoboVoice speech chip
www.speechchips.com

Gordon McComb's robot website tutorials
www.robotoid.com

All-Battery (NiMH battery packs and chargers)
www.all-battery.com

Sseed Studio (Arduino Protoshield boards)
www.sseedstudio.com

Arduino website and tutorials
www.arduino.cc

RobotWorkshop (author's website)
www.robotworkshop.com

RadioShack (local source for Propeller Quickstart, Arduino, and Protoboards)
www.radioshack.com

Steve Norris's beverage delivery system robot (BAXTER)
www.norrislabs.com/Projects/ButlerBot/index.html

Modifying a servo for continuous rotation
www.embeddedtronics.com/servo.html

www.seattlerobotics.org/guide/servohack.html

List of screw sizes and dimensions
www.championscrew.com/machine_screws.htm
http://en.wikipedia.org/wiki/Unified_Thread_Standard
www.hurripanelfasteners.com/tech/screw_size_chart.pdf

particular device, it would be best to ask on the Parallax support forums since someone there is always willing to help.

To finish off the installation, I used a small mono audio amplifier for the RoboVoice chip so it can drive the 8 ohm speaker on the front of the robot. It is mounted on the back of the robot and has a volume control which is a nice option to have.

Building the Arduino-Based Version

For the Arduino-based MiniBot, I ended up mounting the RoboVoice chip and audio amp all on a small board attached to the back of the robot. It has an onboard 3.3V regulator for the RoboVoice since all the other I/O and devices are running at 5V.

We just need a generic shield to plug in that we can use to interface the processor board with all our devices. I used a Sreed Studio Arduino Protoshield that I picked up at my local RadioShack store. This board held a two-pin connector for the head switch, all the three-pin headers to connect to the servos and PIR, and a four-pin header to connect to the sonar module.

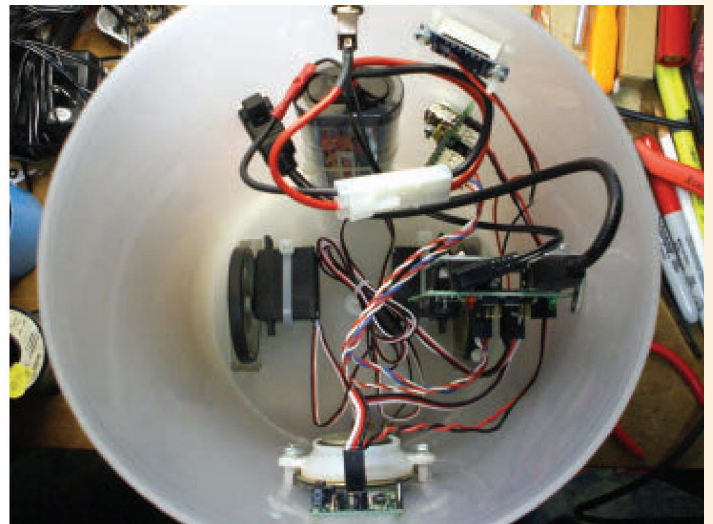
You can set up the I/O on these anyway you like, and it can match what you may have done on previous open chassis robot projects.

Last Minute Upgrades and Fixes to the MiniBots

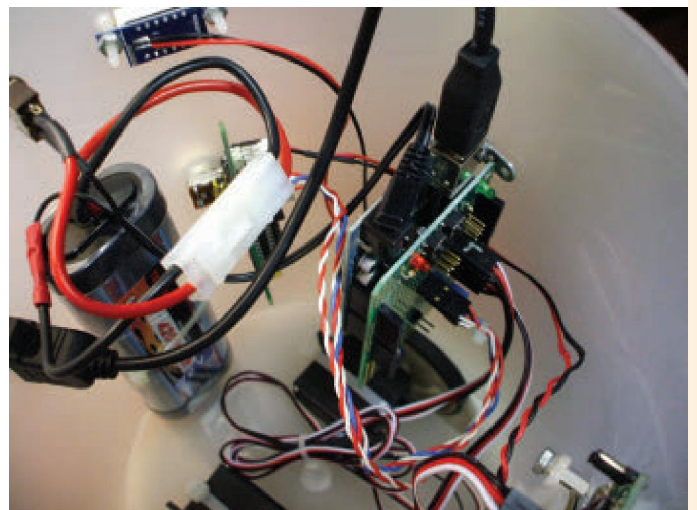
After the MiniBots were built, I ran into a few issues while writing the demo programs for them. The first issue dealt with servo creep on the main drive wheels. While I thought I had set the neutral position on the servo to match the output of the controller, it seemed that one of the wheels would just barely turn and creep along when it was supposed to be idle. The first versions used a regular servo that was hacked for continuous rotation.

Since the adjustments were inside the robot, I had to remove the head to re-adjust them. Once adjusted, a drop of glue helps keep the setting from changing. Because of this, I recommend using the Parallax continuous rotation servos instead, and put a couple access holes on the back of the robot near the bottom so they can be re-adjusted easily without needing to remove the head of the robot.

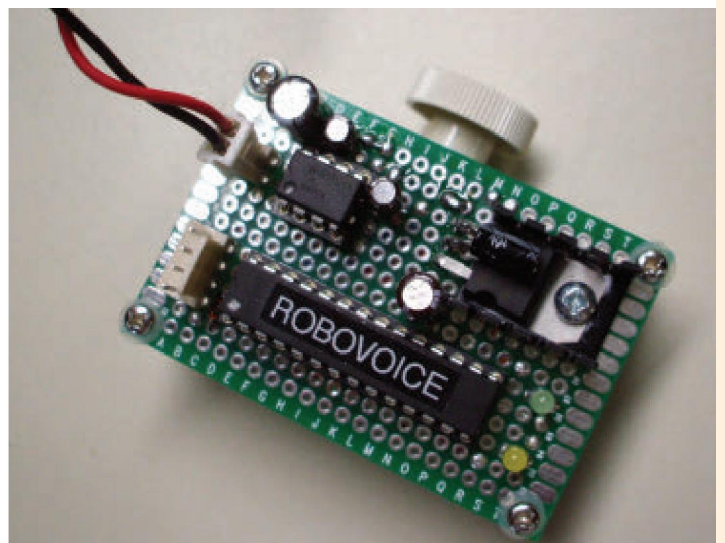
The next issue had to do with the HC-SR04 sonar module. Some of the readings I was getting were off. It seemed that perhaps some of the signal was bouncing back off the swing lid of the can. To help reduce this, I added a small piece of foam around the two metal cans of the sensor. The holes were cut using a small X-acto blade; I cut



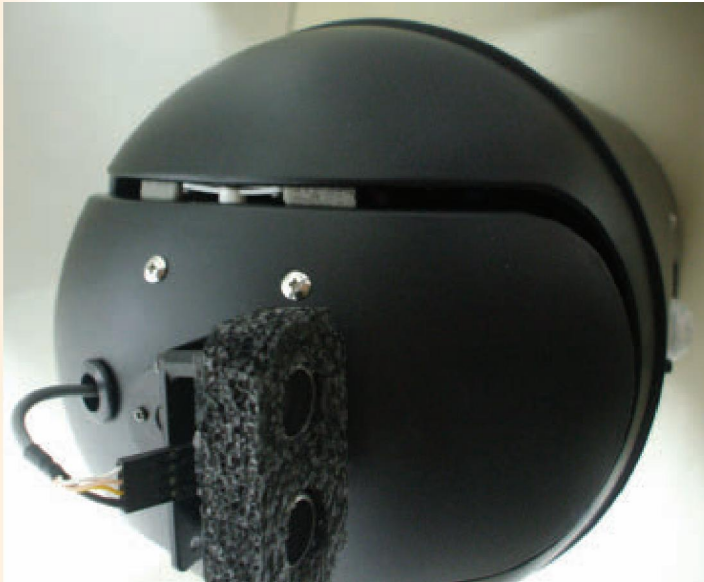
The finished insides of the Arduino based robot.



The finished wiring for the Arduino based robot.



The combo RoboVoice and amp board used on Arduino Minibot.



The lid servo fix by installing foam.

the outer edges with a pair of scissors. With the foam in place, I started getting more consistent readings on the sonar which was in line with what I expected.

The remaining issue I ran into was that occasionally the

lid servo would shimmy/shake while hunting to stop at the desired position. Luckily, the fix for that wasn't too bad. I just cut a couple lengths of non-dense foam weather stripping and installed those on the side of the cover holding the lid. It would gently rub against the lid providing a little resistance — not enough to slow down or prevent the lid from moving, but just enough to dampen the hunting effects. It cured the problem.

Suggestions to Upgrade and Improve the MiniBot

With a good solid platform as the basis for your robot, you can easily enhance it and expand on it. One of the first mods I would suggest is adding a switch between the power lead of the main drive servos.

This way, you have an easy way to disable just the movement of the robot. This helps if you are doing development since you can guarantee it won't try to run away when you are downloading a new version of code to it. This is also useful if you want to use the robot on a desk to make sure it won't drive itself off the table.

I've been installing this feature as a standard part of my larger robots but find that it is an easy mod and worth

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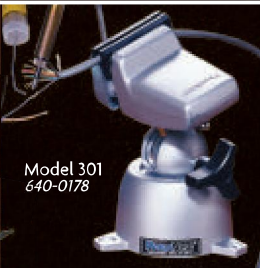


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The robot looking down.



The robot looking up.



adding to the small ones too. If you use a double-pole double-throw switch, you could tie the other side to an unused I/O pin on your microcontroller so it will be able to tell how you have the switch set.

This way, it will know that it can't move around. It would also be a good idea to label all the ports and switches on the robot. I use a Brother labeler to print white on black labels and black on clear labels, which look fantastic on the robot.

Some other goodies to consider adding are a pair (or more) of the QTI line sensors which would enable the robot to perform line following or could help with navigation at a robot competition. An external charging jack or contacts underneath (so it can dock with a charger) would be a good enhancement. Beyond that, just about any other cool gadget out there like a Bluetooth link, serial Wi-Fi link, compass module, Sharp I/R sensors, or bump switches would apply. Of course, a little bling with some LED lighting will enhance the look of the robot.

If you build your own MiniBot, I would enjoy seeing a picture of it and/or hearing from you. Whether you are building robots for school or

just a hobby, I hope you find building your own MiniBot as fun and rewarding as I did.—SV

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3D Printers

This month:

Part 1. Introduction into 3D Printers

Part 2. Assembly Highlights

Part 3. Software and Configuration

Part 4. Tuning

Part 5. Upgrades

Part 6. Conclusion

There has been a great deal of hype around 3D printers lately. If you are planning on purchasing a 3D printer, you may want to wait until you read some of the articles in this series. What I've found out may surprise you.

by Michael
Simpson

www.servomagazine.com/index.php?/magazine/article/may2013_Simpson

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3D Printer Primer

3D printing — also referred to as additive manufacturing — is a practice where objects are created through the process of laying down multiple layers, one on top of the other. There are three common techniques for laying down these layers — each with its own advantages and disadvantages.

Powder Based Process

This process involves using a powder from materials such as plastic, ceramic, gypsum, glass, and even metal. A thin layer of the powder is deposited on the print bed and a binding agent is applied in either inkjet fashion or else a laser is used to fuse the particles. After the layer is fused or bound, another layer of the powder is deposited and the process is repeated. The unused powder acts as a support, so nearly any shape or structure can be created with this method. This technique can quickly create extremely accurate models. The downside to this method is that it is the most expensive, with printers costing upwards of \$100,000.

Photopolymerization

This method involves exposing a vat of liquid polymer to selective light from a DLP projector. After the exposed section hardens, the build platform is lowered and the next layer is exposed. There are variations to this system, and it promises to be capable of creating the most detailed objects.

While this process is not as expensive as the powder based system, it's still out of reach for the average consumer. While this method is starting to gain popularity in the DIY community, the use of liquid polymers and the fact that you have to have cleaning baths for part clean-up may delay its adoption in the average home.

Extrusion or FDM Method

FDM stands for "Fused Deposition Modeling." This method is also referred to as MPD or "Molten Polymer Deposition" and FFF or "Fused Filament Fabrication."

The extrusion method is the most affordable method available. An extrusion based printer in kit form can run as little as \$399. Because of their low cost, these printers

are the most popular printers available at the consumer level, and will be the type of printer I cover in this series.

This method of 3D printing produces the least accurate objects, so it requires the most tinkering. Even the color of the filament being used can affect the success or failure of a print. However, just knowing the limitations can lead to more successful prints, and that is what this series is all about.

How Does the Extrusion Process Work?

A plastic filament is forced through a heated element with a nozzle attached. The nozzle has a very small hole in the range of .3 mm to .5 mm. The filament melts and is extruded through this hole, as shown in **Figure 1**. The size of this hole is one of the factors that determines the final resolution the 3D printer will be capable of.

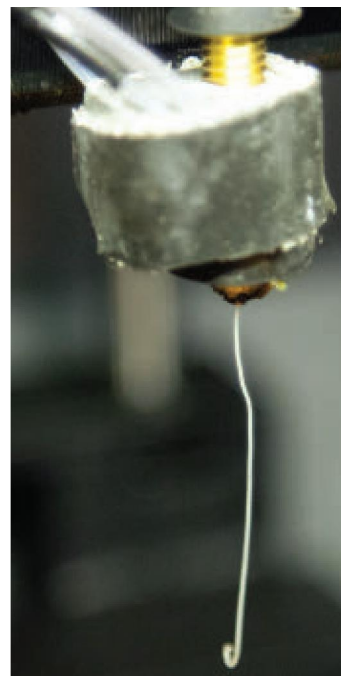


FIGURE 1.

Basic Anatomy of a 3D Printer

The heated element and nozzle is referred to as a "hot end." The part that pushes the filament through the hot end is called the "extruder." The extruder can be directly

driven with a hobbed gear or pulley attached to a stepper motor to push the filament as shown in **Figure 2**.

The filament can also be pushed with a hobbed bolt connected via a series of gears to a stepper motor as shown in **Figure 3**. Some extruders are not connected directly to the hot end. They connect to the hot end via a thin tube called a bowden cable. The bowden cable works much

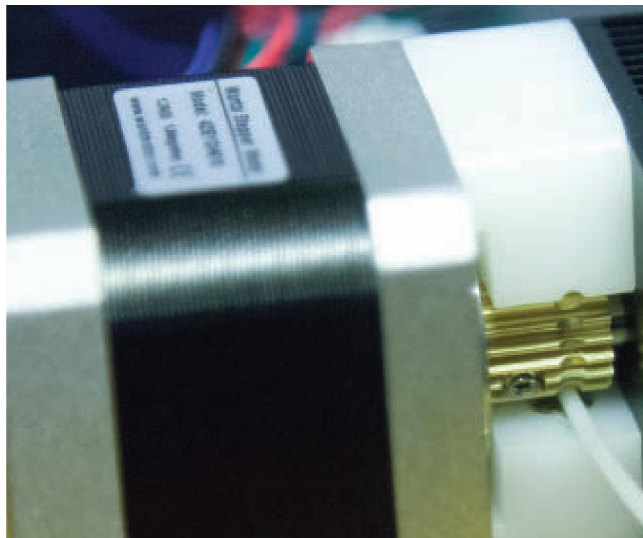


FIGURE 2.

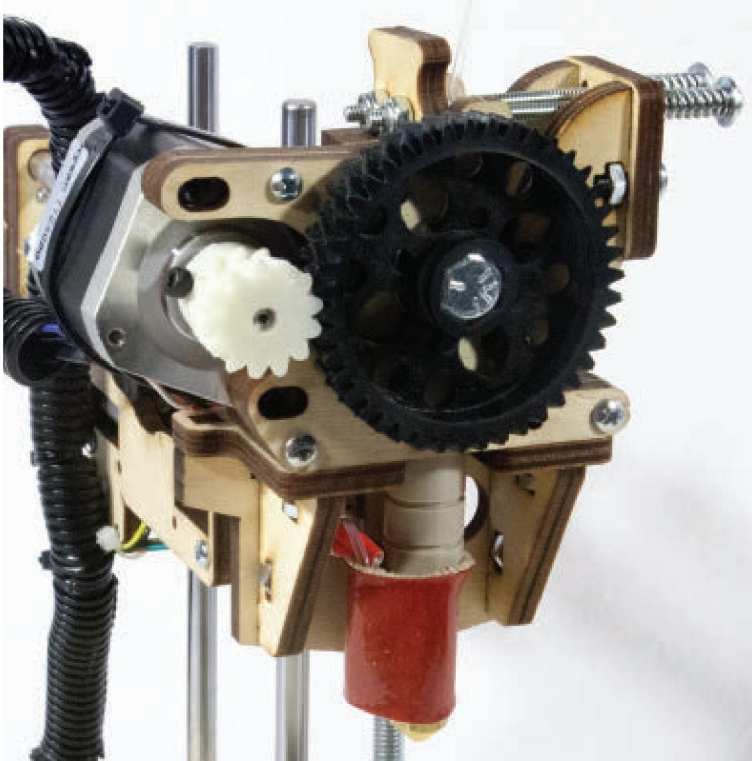


FIGURE 3.

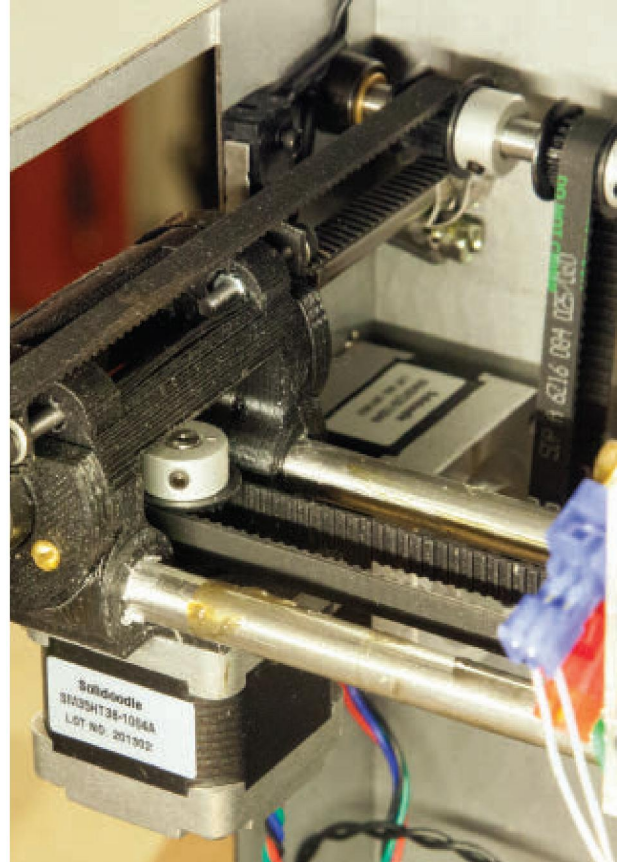


FIGURE 4.

like a brake cable on a bicycle.

Since the goal is to put down a fine layer of plastic, either the hot end/extruder must be moved or the object itself must be moved as the layer is put down. In reality, this is often a combination of both. This is achieved with at least one stepper motor on each of the X, Y, and Z axes. Often a timing belt and pulley is used in conjunction with the motor as shown in **Figure 4**.

The stepper motors are maneuvered with a controller much like the one shown in **Figure 5**. This is a RAMPs board, and it and its variants are very popular in the 3D printer world.

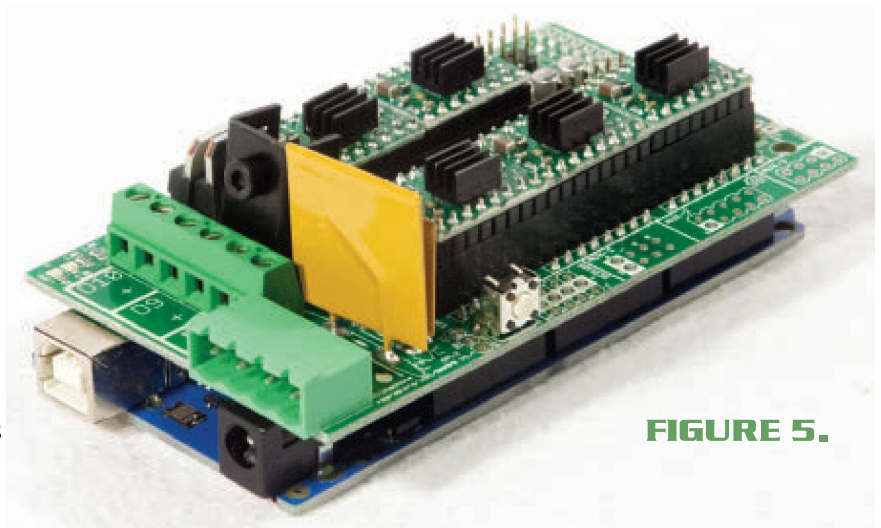


FIGURE 5.

Sanguinololu is a low cost all-in-one electronics solution for Reprap and other CNC devices. It features an onboard Sanguino clone using the ATMEGA644P, though an ATMEGA1284 is easily dropped in. Its four axes are powered by Pololu pin compatible stepper drivers.

The board features a developer-friendly expansion port supporting I²C, SPI, and UART, as well as a few ADC pins. All 14 expansion pins can be used as GPIO, as well.

The board is designed to be flexible in the user's power source availability, allowing for an ATX power supply to power the board, or the user can choose to install a voltage regulator for

use with any power supply 7V-30V.

Teensylu is based on Sanguinololu. The ATMEGA644P has been replaced with an Atmel AT90USB1286 MCU. This microcontroller has on-chip USB, removing the need for the FTDI USB UART. All of the through hole resistors and capacitors have been replaced with 0805 SMT components (as of Ver 0.1).

Like the Sanguinololu, the Teensylu has expansion headers supporting I²C, SPI, UART, and ADC pins. All extra I/O ports of the AT90USB have been broken out to headers for prototyping.

Courtesy of Wikipedia.org

3D Printer Features and Details

As I started my research into the 3D printer world, I purchased three very different 3D printers. This way, I could see both the advantages and disadvantages of the various designs. Let's take a look at each printer in detail.

PrintrBot Jr

At a price of \$400 in kit form, this is easily the lowest priced 3D printer on the market. The kit comes with everything you need. It even comes with a pound of filament to get you started. For an extra \$100, you can purchase the printer fully assembled. If you don't like building such things, this might be an option that would appeal to you.

The main construction material is 1/4" birch laser cut plywood. The extruder/hot end moves on the Y and Z axis. The table moves on the X axis. The X and Y axis utilize timing belts. The rails consist of two 8 mm rods on each axis with four linear bearings, allowing for very smooth linear motion. This is a plus for such a low priced printer. The Z axis is driven by a 1/2" threaded rod and nut.

The printer (shown in **Figure 6**) has a printing area of 4.5" x 5.5" x 4". As sold, it's designed to print PLA only, as it does not come with a heated bed.

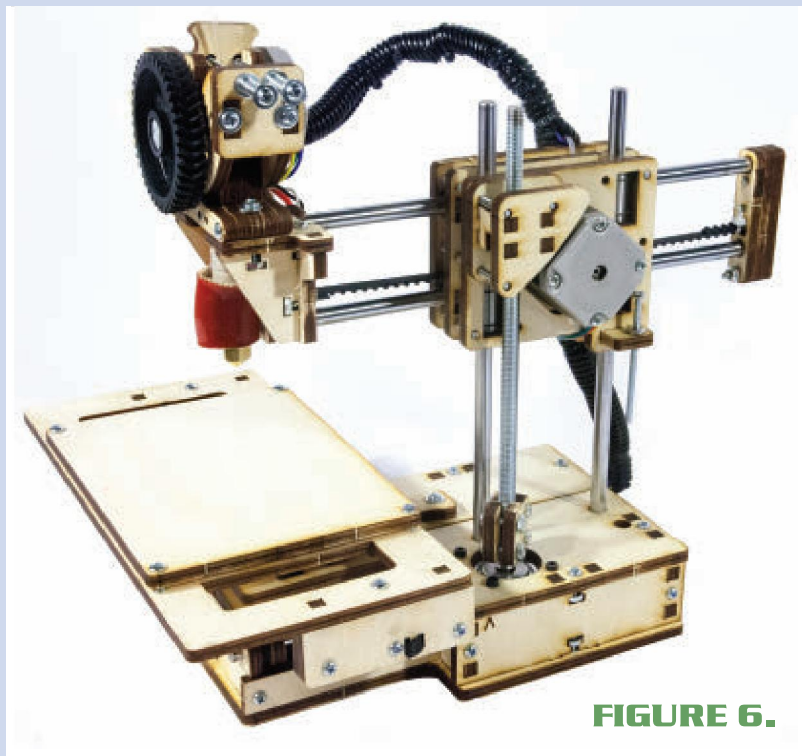


FIGURE 6.

PrintrBot Controller

The controller (see **Figure 7**) was redesigned by the Printron team. The board — called Printronboard — is a derivative of the Teensylu board based on the Sanguinololu board. The board comes with Marlin V1 Sprinter firmware installed, but is firmware upgradable if needed. It has four

stepper drivers, so a second extruder is not in its future.

The board does have provisions for both an extruder fan and heated bed. Both are important upgrades you will need. The PrintrBot Jr folds up and takes up very little space. However, its open design might not be a good fit if you have smaller children running around.

The extruder utilizes a gear drive, so there is a lot of torque. It also features a spring loaded tensioner that has a quick release for fast filament changes and maintenance. The hot end is a 1.75 mm Ubis cartridge with a .4 mm nozzle.

As a bonus, the controller board contains a microSD slot, so it is possible to save your work to the card for onboard printing. You must tether to your PC to start this process.

You can get more information about the PrintrBot Jr at <http://printron.com/>.

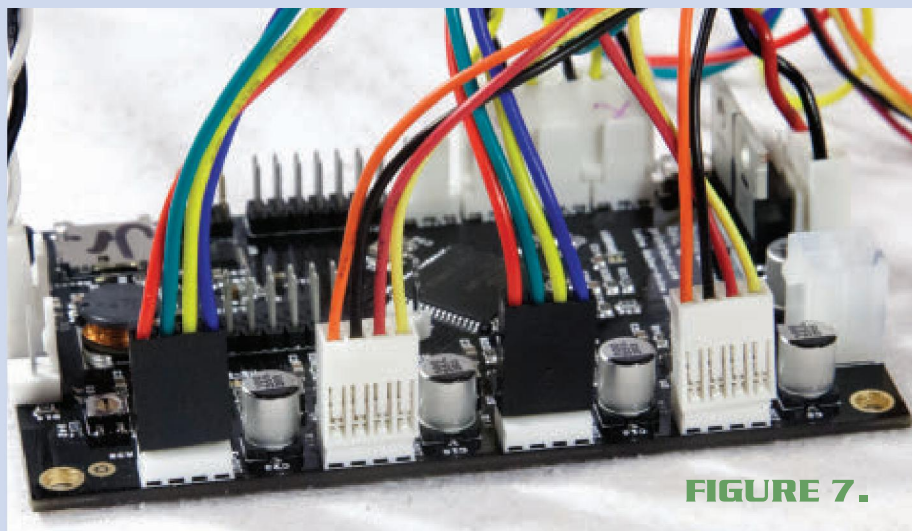


FIGURE 7.

Rostock Max

If the PrintrBot Jr is the smallest 3D printer, then the Rostock Max is the largest.

This Rostock Max is only available in kit form. The shopping cart states the main construction material as wood. It is not. It's 1/4" melamine coated MDF (medium density fiber board). For an extra \$175, you can get it in acrylic.

The extruder/hot end is stationary and sits off to the rear of the machine. The table is also stationary. The three extruded aluminum legs act as rails for custom ball bearing runners that attach to three plastic arms. These three arms come together in the center and form a delta robot platform that can move in any direction very quickly. The platform holds the hot end that is connected to the extruder through a thin tube that acts as a bridge for the filament.

The printer (shown in **Figure 8**) has a printing area of 11" diameter with a maximum height of 14-3/4". It comes with an 11" heated bed and can extrude PLA, ABS, PVA, and nylon.

Rostock Max Controller

The Rostock Max uses a Rambo controller shown in **Figure 9**. This is one of the most powerful 3D printer boards available. It comes with five stepper controllers, so you can upgrade the Rostock Max to a dual extruder printer. It also has extra fan outputs and temperature inputs for fans to keep the parts cool.

The board comes with a special version of Marlin firmware installed, but must be upgraded before you can use the printer. This means you need to download the Arduino IDE and proper firmware. You can get more information about the Rostock Max at <http://shop.seemecnc.com/>.

FIGURE 9.

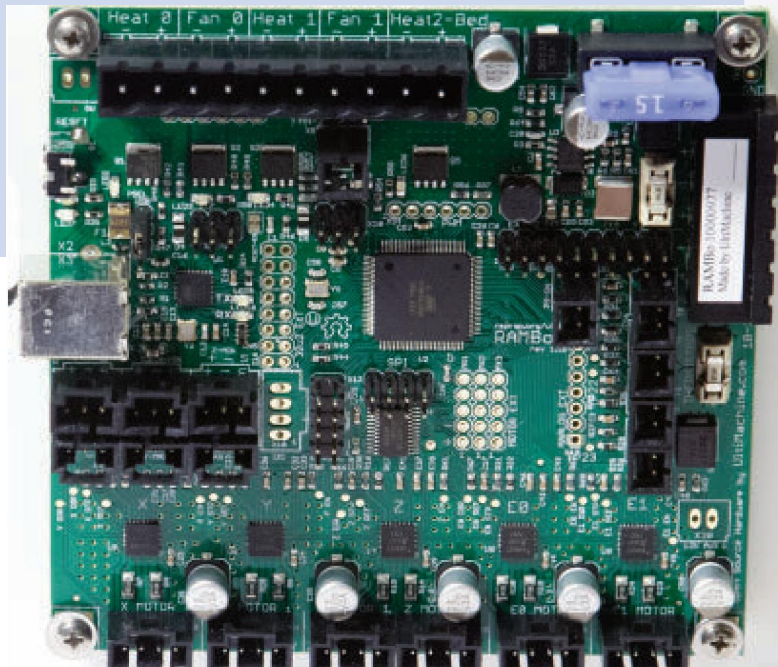


FIGURE 8.

The leading developers of Marlin are currently EvdZ and bkubicek, though many others contribute with their patches. This is a firmware for reprop single-processor electronics setups. It also works on the Ultimaker PCB. It supports printing from SD card+Folders, and look-ahead trajectory planning. This work is licensed under the GNU GPL v3 or (at the user's discretion) any later version. It is based on Sprinter firmware, which was licensed under GPL v2 or later.

Courtesy of Wikipedia.org

Solidoodle 2

The Solidoodle 2 is the lowest priced turn-key 3D printing system available. The Solidoodle 2 comes fully assembled, tuned, and ready to print.

The base model sells for \$500; this gets you the printer but no heated bed. For \$100 more, you get the pro model that does include the bed.

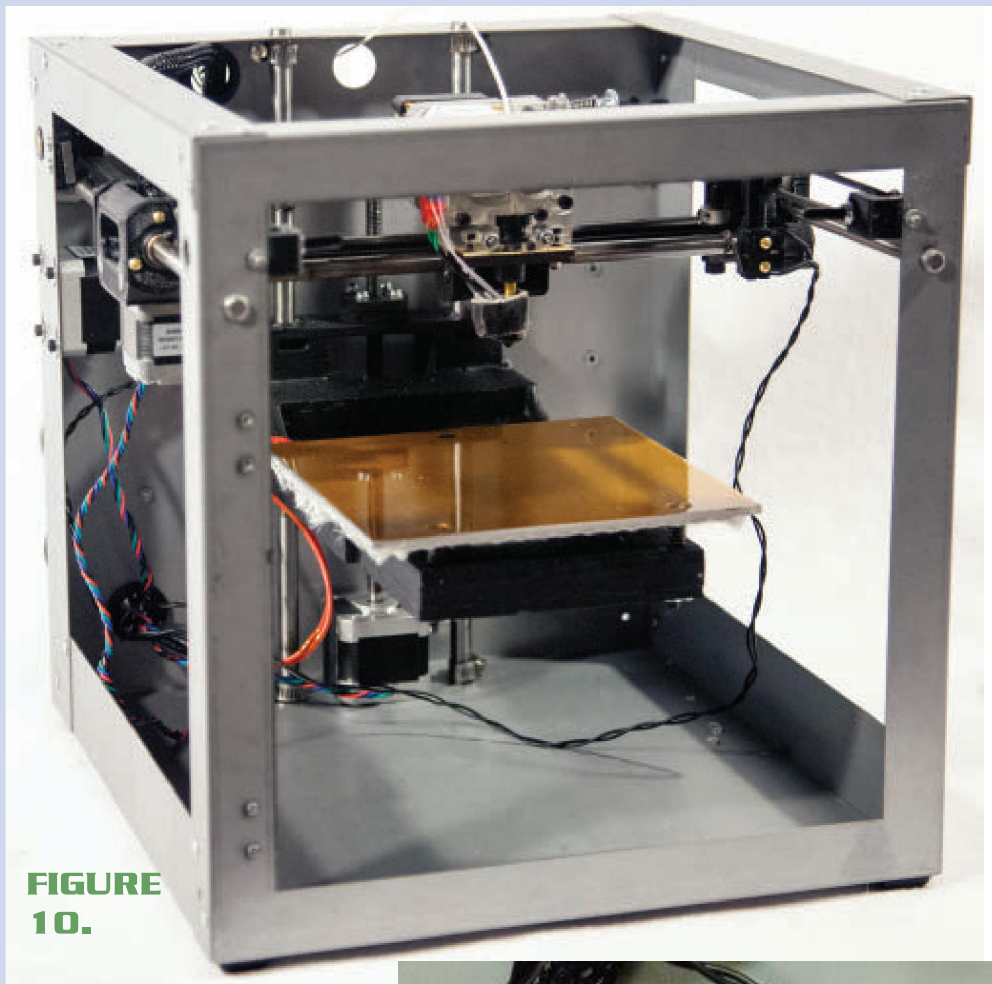
The PrintrBot Jr is considered a moving bed; the Rostock Max is a delta bot; and the Solidoodle 2 is a gantry system. Many of the mid to high range printers use this system, where the extruder/hot end moves on the X and Y axis, and the bed moves up and down on the Z axis.

The Solidoodle frame is made from 1/32" thick sheet metal. The X, Y, and Z rails are dual 8 mm steel rails. Unfortunately, instead of bearings the Solidoodle utilizes bushings.

The remainder of the components are plastic except for the main platform which is made from wood, but is coated with some sort of plastic. The heated bed version of the Solidoodle has a 1/8" aluminum bed covered with Kapton tape.

The Solidoodle 2 (shown in **Figure 10**) has a printing area of 6" x 6" x 6".

FIGURE 10.



Solidoodle 2 Controller

The Solidoodle 2 utilizes a Sanguinololu board. (Refer to **Figure 11**.) This is the least expandable board of the bunch. While it supports a heated bed, it does not support a part cooling fan or dual extruder without extensive mods.

The board comes with Marlin V1 Sprinter firmware installed, but is also firmware upgradable if needed. You can get more information about the Solidoodle at <http://store.solidoodle.com/>.

FIGURE 11.



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Courtesy of Wikipedia.org

Kits or Assembled

There are three ways to acquire a 3D printer:

1. Turn-Key

A turn-key 3D printer will come ready to print, with little or no assembly. For instance, the Solidoodle 2 comes with a filament holder that takes about 20 seconds to assemble and attach to the printer.

Little or no tuning should be required with this type of printer. You will, however, be required to install the software.

2. Kit

In this series, I will be assembling two kits — one of which can be purchased assembled. You must understand that the assembly process is very extensive. Both the PrinrBot Jr and Rostock Max assembly times given on their websites were inaccurate. The assembly took considerably more time than indicated. That said, I enjoyed building both printers and learned a great deal during the process.

Another aspect that is often overlooked when assembling your own 3D printer is the tuning factor. The tuning process can take almost as long as the assembly time.

3. DIY

This type of 3D printer will require the most work. You will have to do a lot of research, and may have to fabricate many of the components. Assembly will take days instead of hours, and the tuning process may require trial and error since you might not have anything as a reference.

Most likely, you will be using the same controller and software, so that process won't change. The main advantage to a DIY build is that it can be done considerably cheaper.

Note that many of the 3D printers currently available are open source designs with drawing files offered on the respective websites. There are also third-party companies like **ultimachine.com** that offer many parts that can be used in a DIY build.

Conclusion

I have a lot of information to present to you. I had various problems with some of the printers, some of which I have fixes; others, I am still working on. It is my plan to work them out as this series progresses.

Next time, I will be presenting some assembly highlights of the PrinrBot Jr and the Rostock Max printer kits. We will also be un-boxing our Solidoodle 2 machine. **SV**

A delta robot is a type of parallel robot. It consists of three arms connected to universal joints at the base. The key design feature is the use of parallelograms in the arms, which maintains the orientation of the end effector.

Courtesy of Wikipedia.org

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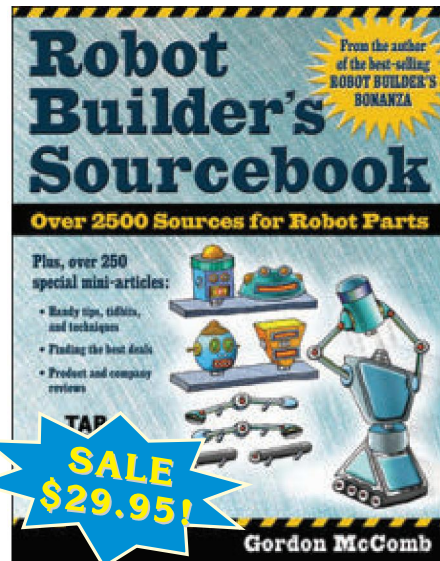


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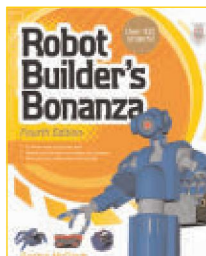
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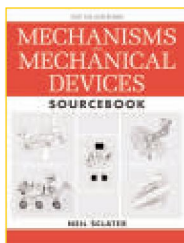
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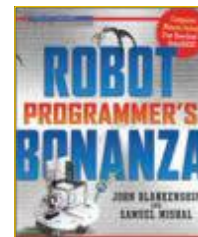
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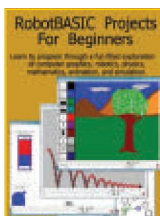
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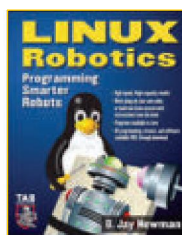


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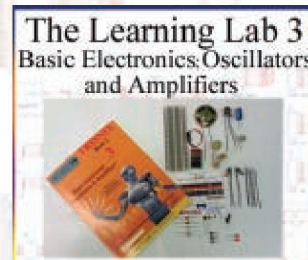
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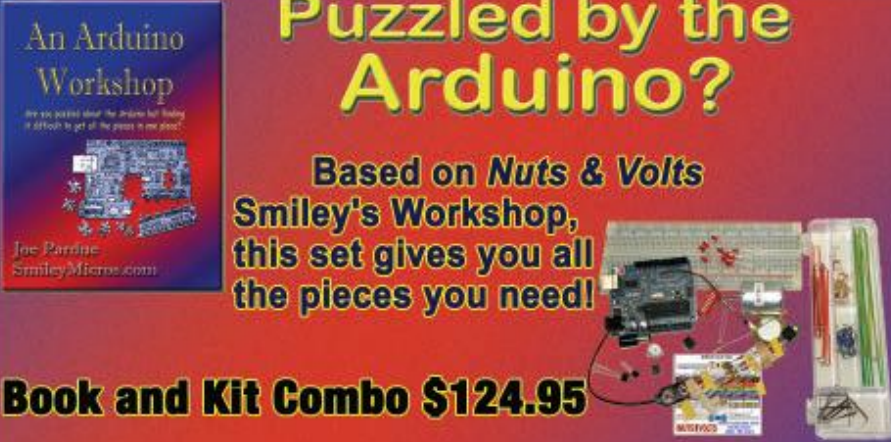
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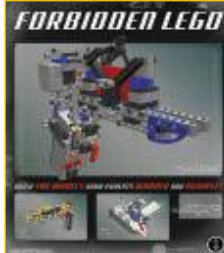
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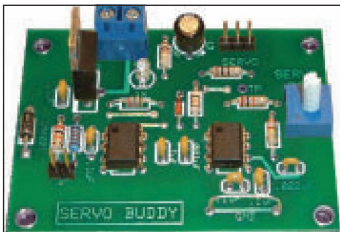
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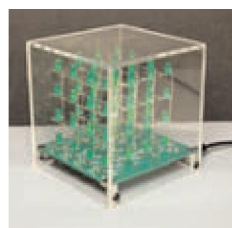
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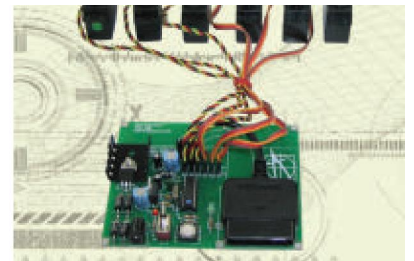
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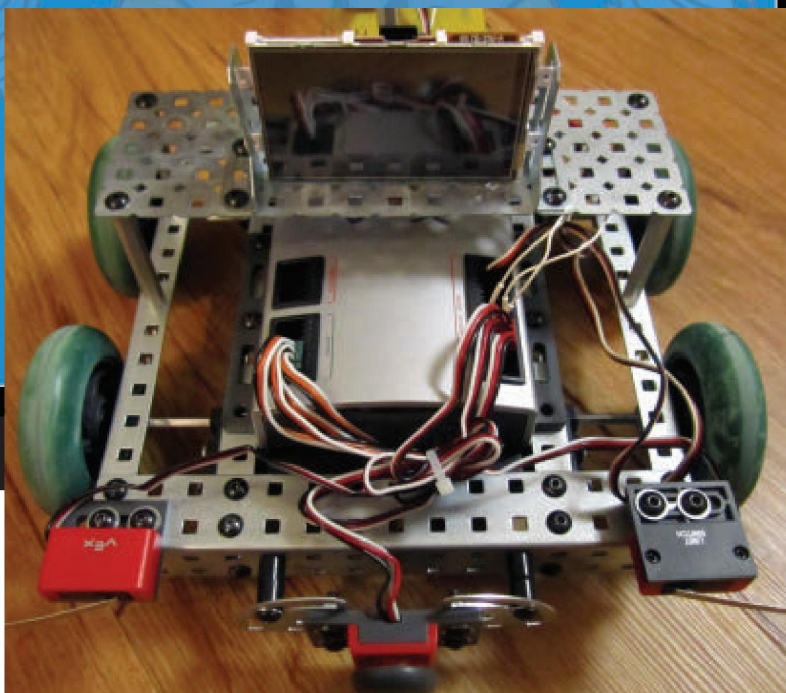
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A VEX BOT EQUIPPED WITH A SMART MODULE.

This month, we aim to explore the full potential of the smart display modules from 4D Systems that we introduced in the March 2013 issue. Last time, we became oriented to the smart LCD and OLED modules, and created a simple face using the Visi interface. This time, we want to add some expressive range to the robot, and we wanted to coordinate the expressions on the smart modules with sensor input from the robot.

Could we integrate the smart modules into a robot so that both the screens and the bot responded appropriately to stimuli? Would the components co-exist peacefully as a harmonious symbiote, or hopelessly clash like Frodo's goodness and honor and the seductive power of the One Ring? Just like a Hobbit breakfast, all of this would be wrapped up in the second installment.

Who's Afraid of the All Seeing Eye?

The smart modules from 4D Systems are meant to add an artistic flair to existing projects or even act as a stand-alone unit. The smart modules — which come in both LCD and OLED flavors — are equally comfortable as passive displays or interactive gauges.

The most intuitive interactive applications involving the smart modules, however, mostly involve just the smart module and some sensors. The touch screen modules in particular have built-in objects like sliders and buttons that

allow users to interact with the module through the screen.

Digital in/outs also provide the opportunity to use some sensors to interact with the module, but that generally means interacting with a stationary module. Sure, the module could be mounted on a robot and used to display things like motor RPM or the position of a mechanism, or feedback from sensors, but it would be more of a mounted accessory instead of an integrated part of the robot. The modules can't source the power necessary to power motors, so the module and the robot would never truly be as unified as Gollum hoped to be with his Precious.

Last time, we were able to get the smart modules operating off of the same power source as a VEX robot base. The 4D Systems smart modules are about as ravenous as an elven archer, and could be powered off one of the I/O ports on the VEX brain. Jumper wires from the +5V and the ground of the VEX I/O port to the appropriate pins on the smart module is all that it took to bring the smart modules one step closer to unity with the robot.

The first order of business was to give the bot a more expressive face. The rudimentary face we had pieced



THE EYE OF SAURON SEES ALL ...



CHOOSY DEVELOPERS CHOOSE GIF.

together in VisiGenie wasn't even really fit for a Jack-o-Lantern — much less an expressive automaton. One of the great things about the smart modules is that with the SD cards, you go a little crazy with whatever you want to load

onto the modules — photos, animated GIFS, even full-on video files. What we were looking to do was give our robot a face, and we had two screens to do it.

Our widescreen LCD module looked like a good size for a mouth, and our smaller square OLED module seemed appropriate for an eye. With only one OLED module for an eye, it looked like we would be making a Cyclops. We knew our bot would be at a little bit of a disadvantage with just one ocular addition, so we knew we had to make it count. So, what better way to do that than to make the bot's one eye the all-seeing Eye of Sauron? Sometimes one eye is all you need (though thankfully our bot wouldn't need to fix its gaze on an entire Fellowship).

We tracked down some appropriate pics on the Internet with the goal of loading a few still images onto the module. At first, we would simply have the images cycle through a slide show of sorts after a pre-set delay. After getting that sorted out, we could replace the simple pause functions with reactions to sensor input.

As with any good project, we got sidetracked along the way. Finding some animated GIFs of the Eye made us wonder how animation would look on the screen. We downloaded the GIF, loaded it onto the SD card, imported the image into Visi, pasted in the code, then compiled and downloaded. The screen beamed to life, and we were delighted to see the Eye of Sauron burn with watchful fury on the small screen.

The animation was crisp and smooth, and demonstrated that the tiny OLED is more than capable of handling any sort of display need a user might have.

The Two Modules

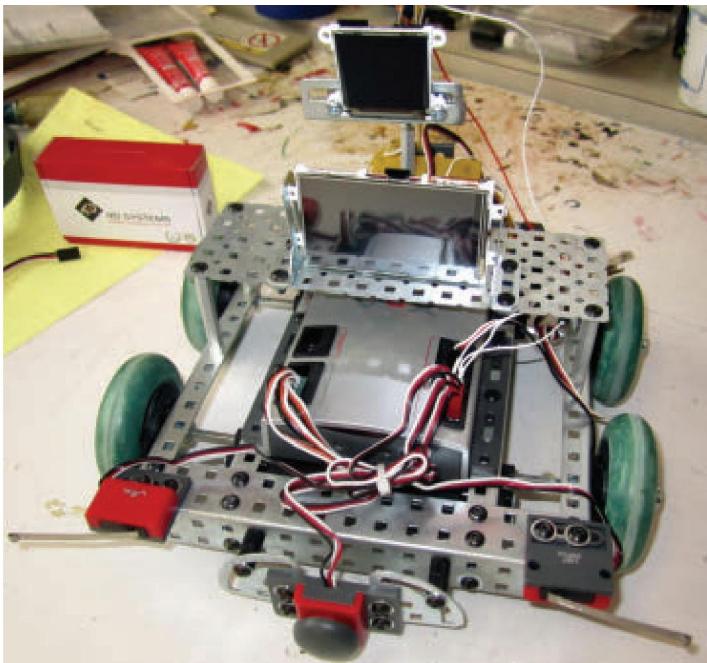
After loading the GIF onto the OLED screen, we wanted to continue with our planned path of loading on several images to the screen, with the eventual goal of having the images change according to sensor input.

This leg of the project demanded a lot more work with the software, and we picked up some tips on how to best work with the Visi interface. Unlike the flat effect of our bot last time, we wanted a robot with some emotional range. The best way to do that would be to use more than one simple image for the bot's face.

A good first step along the path to facial expressiveness was to put two pictures onto the screen which could change as if the bot were changing expressions. Since we already had some inspiration for the look of our bot's all seeing eye, we tracked down two terrifying pictures of the sinister Eye of Sauron to load onto the μ OLED-128-G2 module.

For starters, we just wanted the module to switch from one picture to the other after a few seconds, just to experiment with two different expressions.

Using the toolbar in the Visi interface, we loaded the first picture onto the screen. We resized it appropriately,



ADDING SOME EXPRESSIVE RANGE.

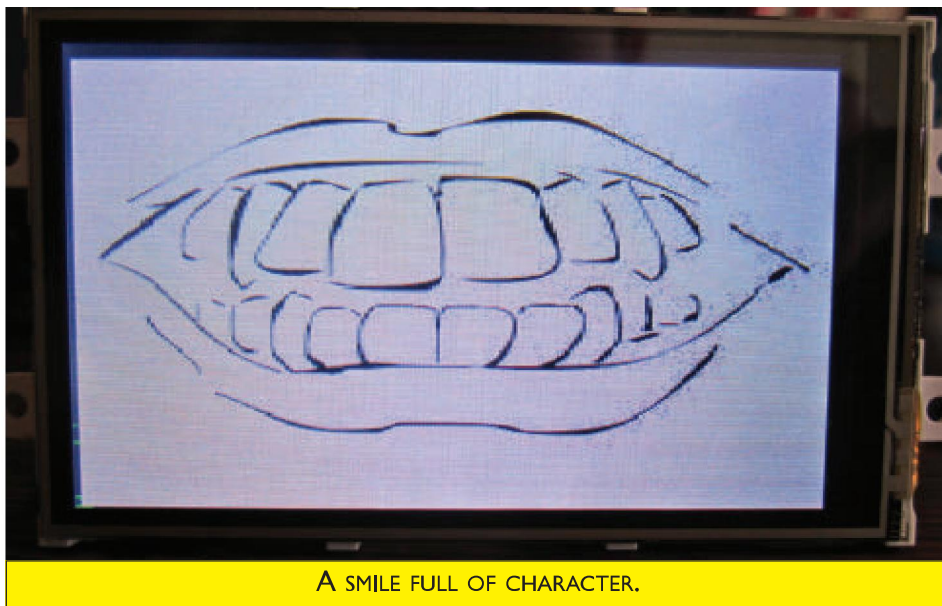
pasted in the code, then tried to put in the second picture. Clicking the import image button on the toolbar, however, did nothing. After a few moments of frustration, we discovered that the import image button only worked when the screen in the Visi interface wasn't full – you need to click on an empty spot on the screen to import the image.

With that hurdle cleared, we had the skeleton for our code. We added pause commands between the images so each image had the chance to shine. After compiling and downloading the program, we were thrilled to see a forward looking Eye switch to one looking askance at the viewer. Now that we had the basics down of how to load multiple expressions onto the modules, we needed to sort out how to get those expressions to change according to sensor input.

Instead of having to wire up the whole robot while we were still in the debugging stages, we thought that the LCD touch screen module would be the perfect self-contained way to sort out the programming. If we could get the expression on the screen to change according to touch screen input, the programming should be easy to translate to the touch sensor context. Now that we were working with a different screen, we had to find more images for it. After a few quick searches, we found some quirky mouth images with cartoonishness that was an amusing contrast with the vengeful seriousness of the bot's all-seeing Eye.

Now that we wanted to do some real programming, we were compelled to investigate the instructional resources that 4D Systems had to offer. The Designer programming is a bit like C, but we thought trying to fumble through the programming without a proper understanding of the commands or syntax would be like hoping your Spanish could get you by in Italy. The 4D Systems website includes a host of helpful documentation on the page for the 4D Workshop 4 IDE. The general reference manuals on the IDE deal more with basics, like installing the software and a Hello World type introductory program.

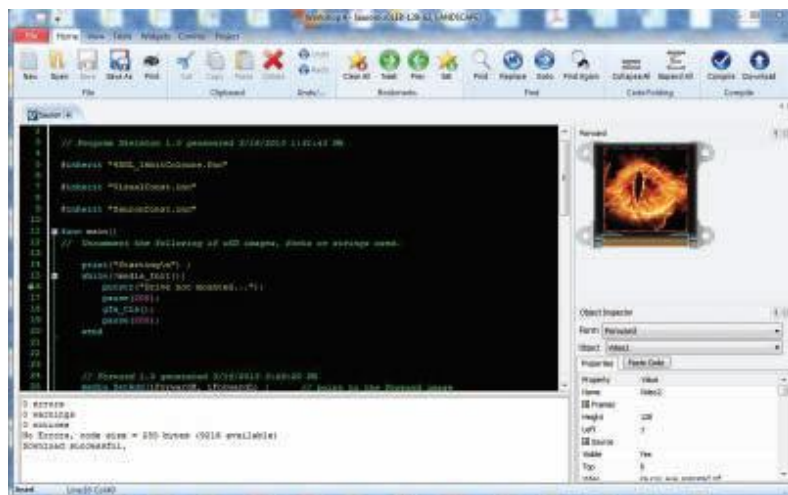
The really helpful material comes in the form of



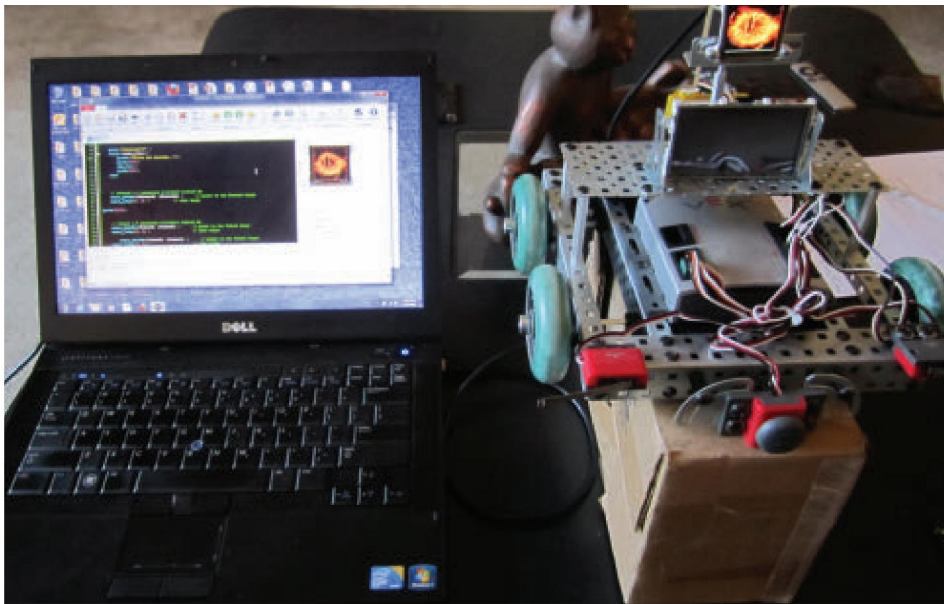
A SMILE FULL OF CHARACTER.



HAVING A LITTLE TASTE.

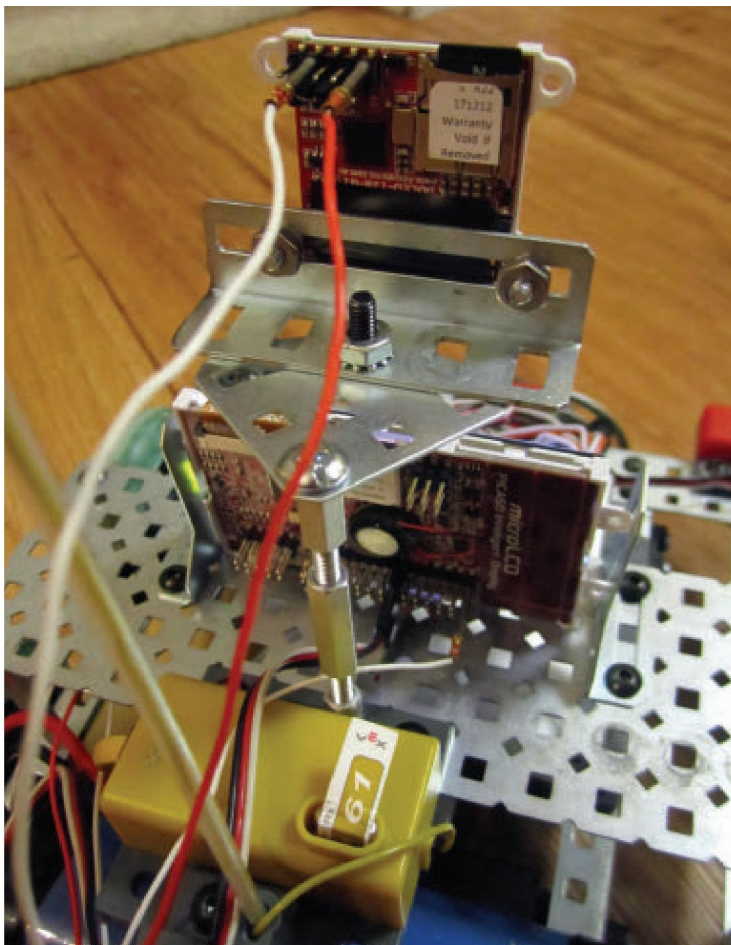


PUTTING IT TOGETHER IN VISI.



PROGRAMMING THE BOT.

reference manuals for the internal functions of the graphics processors: GOLDELOX and PICASO. The reference manuals



CREATING A SYMBIOTIC RELATIONSHIP.

are voluminous documents that detail the hundreds of internal functions that accompany the processors. Each entry in the manual describes the basic use of the function, including the syntax and a short example chunk of code. The examples are merely chunks of code because they don't define variables or lay any of the other groundwork for a working program – they simply want to help you avoid a syntax error when using the native function. After perusing the internal touch screen commands for the PICASO processor, we were ready to dive into the Designer environment.

Since our new project was more programming intensive than our last, we were able to notice a few more things about the Designer environment. One aspect that we

found particularly helpful was the fact that the colorful text as vibrant as the first trip to Oz could act as a guidepost for syntax. Different aspects of the programming syntax showed up in different colors. One of the specific ways in which this was helpful was with using the internal functions. The internal functions would appear in a light blue color, as opposed to the greens and purples that characterized other chunks of the program.

This was particularly useful because the text would only change color to light blue once the internal function was typed in correctly. This may not sound like much, but when you're typing in code, the color change is a nice way to affirm that you're typing in the functions correctly. Plus, it's a nice reminder to check things like the letter case when the text doesn't change color as expected.

Colorful text is actually not that unusual to find in a user-friendly IDE, but another aspect of the Workshop 4 IDE is a bit more exotic. Once the user types in an internal command, a box of what looks like hover text appears. The box contains a detailed rundown of the internal command. It's actually quite like having an in-IDE manual, and it's a lot more convenient than having to scroll through the massive PDF or flip through pages in a binder. Of course, to get the hover text to appear requires you to type in the internal command properly, but that's not too much to ask.

With vibrant colors and hover text as our guide, we wrote a simple program that would cause the LCD module to display one picture as a default (a toothy smile) and display a different picture upon getting touched (sticking its tongue out). After the regular back and forth of fixing missing semicolons and the like, the program compiled successfully and downloaded to the module's SD card.

Since the programming cable sourced power to the module, we were able to test the program in situ after retrieving the SD card from the computer. The toothy smile appeared as expected. Upon touching the screen, it switched to the tongue picture, as if the screen was trying to get a taste of the trespassing finger.

As an aside, we were impressed by the capabilities of the touch screen. The internal commands allow the user to set specific regions of the touch screen as responsive to different inputs. Given the size of the widescreen LCD module, it could make a nice touch pad controller for a bot, and premade button objects in the Visi interface would make putting it together a breeze.

VisiGenie would even allow the design of such a controller without having to type in code at all. After importing a button or other object into VisiGenie, users simply assign events to correspond to button input in an easy to use table.

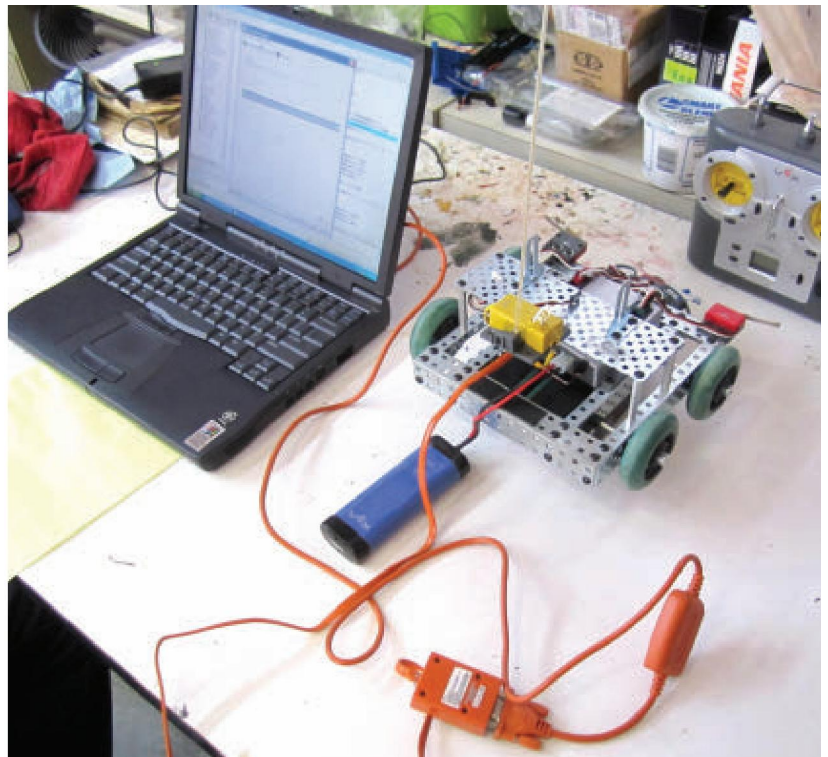
Cutting Through Shelob's Web

With the touch screen programming sorted out, the power of analogical reasoning made programming the OLED module a cake walk. To change from one expression to the other, we used a simple if-else construct and the GPIO internal functions. We programmed the screen to switch from a still picture of a forward gazing Eye to the animated GIF of the burning Eye when a certain digital input pin read high. Of course, we needed a sensor to create that input, so we couldn't as easily test our program and we had to get the robot base ready first.

The VEX robot base was equipped with two limit switches at its front corners and a bumper sensor in the middle. Each sensor could be wired to a different digital input on the smart module, allowing for a different expression every time the robot encountered a differently positioned obstacle. The challenge here was to really integrate the smart modules into the robot.

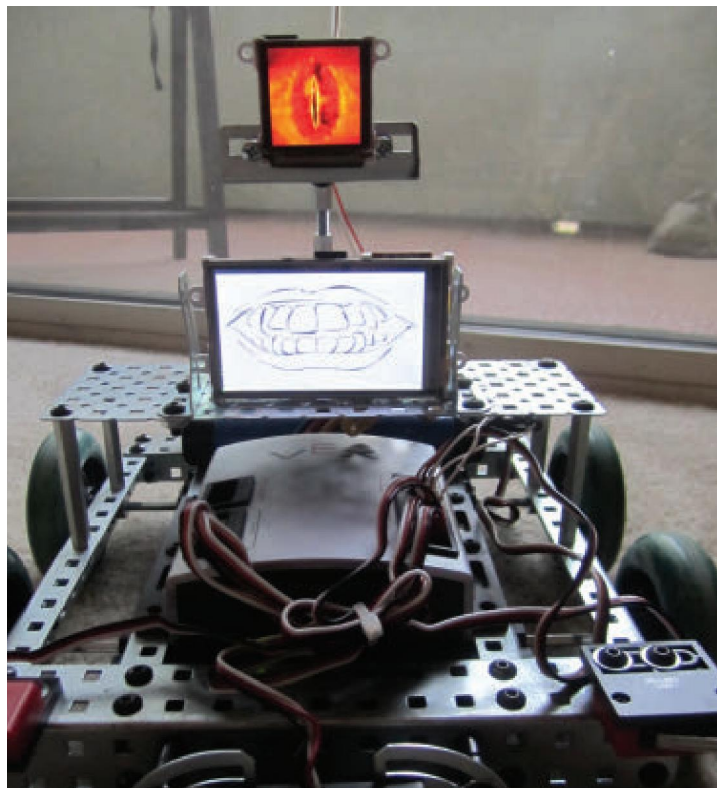
Instead of passive displays, we wanted the bot's face to react to the exact stimuli that caused the robot to avoid obstacles autonomously. At a high level, the solution is simple – wire the signal lead from the sensors to both the VEX brain and the smart modules. The most obvious way to do this, however, had its own set of entanglements. The most uninspired way to do this was to splice three leads onto the signal wire of each sensor. One would go to the VEX brain, and the others would go to each smart module. This, however, could quickly escalate to an unmanageable web of wires. There had to be a better way.

Of course, there was. Instead of splicing together wires with wild abandon, a better solution was to leave the wires on the sensor alone and have it plug into the VEX brain

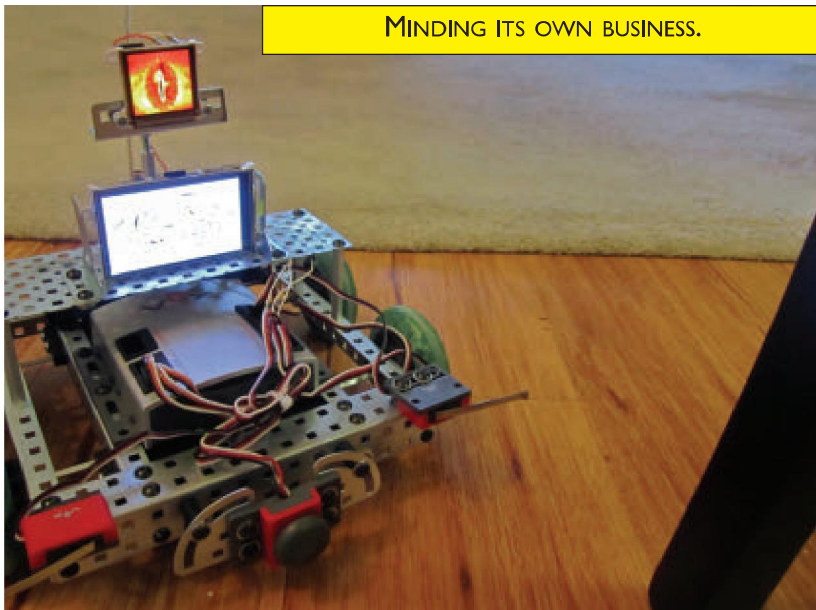


SORTING OUT THE VEX WITH EASY C.

normally. The smart modules could then wire into digital output ports on the brain itself. This might not cut down



READY TO FACE THE WORLD.



MINDING ITS OWN BUSINESS.

After confirming that we had a nice consistent high reading of 5V from the digital outputs upon pressing a sensor, we were ready to wire up the smart modules.

With the robotic base electrically prepared for the smart modules, we had to make sure it was structurally prepared too. The smart modules come equipped with some convenient mounting holes. The hole diameter is a little smaller than the basic VEX fastener, but with a strategically placed washer, it would fit together nicely.

One detail about the layout of the smart modules that we really appreciated was that the pins that connected to the programming cable were situated on the top edge of the module, making them easily accessible so that the modules could be programmed even in place on the robot.

There and Back Again

on the ultimate number of jumper wires required, but it would avoid the necessity of messing with the signal lead coming out of the sensors, and keep them pristine for future projects.

To sort out the digital output ports that would correspond to the bot's sensors, we mapped the ports on the brain and confirmed with a digital multimeter (one of the handiest tools a tinkerer can have in his or her arsenal).

With the modules programmed and mounted, it was finally time to test the robot. We had programmed the VEX base so that it could be remotely controlled by radio, but that it would react autonomously to obstacles by backing away and turning when it encountered something that activated one of its sensors.

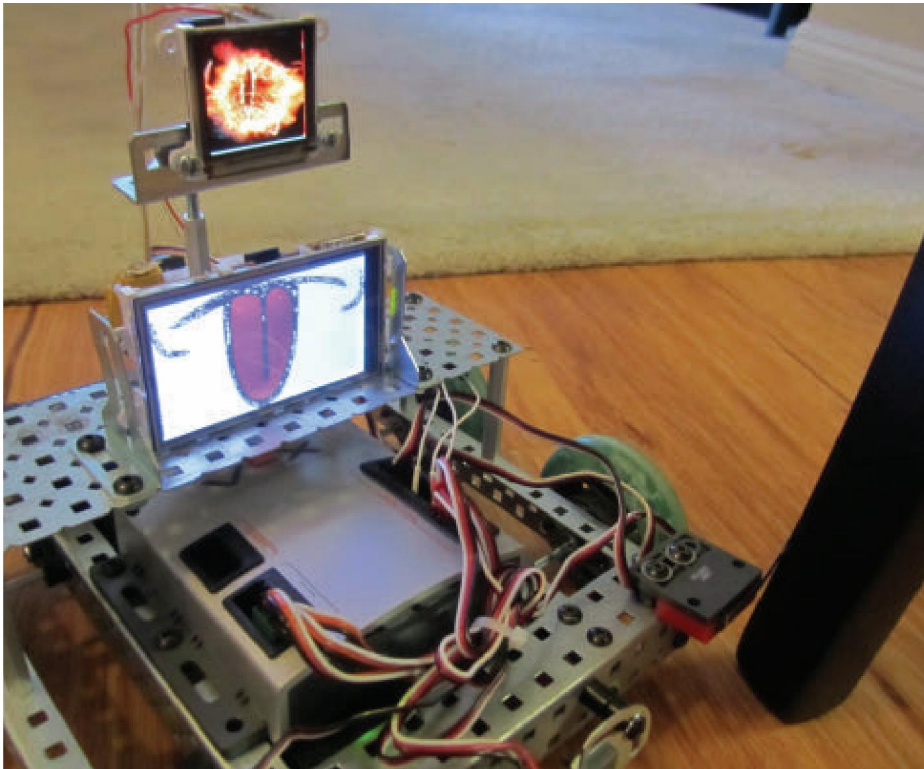
We set up an obstacle for it to run into, and hoped the robot's expression of a stoically forward looking Eye and

goofy smile would change to a burning Eye and outstretched tongue upon contact. When we mercilessly crashed the bot into the obstacle, we were delighted to see it autonomously back away while registering its displeasure with a change in facial expression.

The modules had been successfully integrated into the robot. With a little electrical and programming ingenuity, the smart modules can be used as much more than passive displays.

Similar techniques could be used to develop the type of touch pad controller mentioned above, or just about any other robotic application that could use a dash of artistic flair.

Even though the robot face here was certainly more on the aesthetic and whimsy side, don't be surprised if you see the modules pop up in more practical capacities in our future projects. **SV**



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Then and NOW

Why a Robot?

by Tom Carroll

You might be wondering just what I mean by that title. This is a magazine about robots, so what exactly am I getting at? I'm going to step away from hobbyist machines and look at some robots that have been in the news and discuss reasons for using them. Why or why not use a robot in the place of a human? Some of the robots that I will talk about may be considered industrial, medical, or space robots, or — in one case — a supercomputer. The trend now seems to be the development of robots to work in close proximity with humans. If you'll recall, some of the early science fiction stories of the '50s and earlier showed robots in factories working beside human employees. It is happening in actuality today.

I was recently in the Sacramento, CA area on a business trip. While at the airport waiting for my return flight, I was browsing through some magazines. The "Robot Will See You Now" on the cover of *The Atlantic* magazine shown in **Figure 1** caught my eye. The article by Jonathan Cohn was not about surgical robots such as Intuitive Surgical's da Vinci robot, but rather about using a supercomputer to make medical diagnoses.

In the article, it was mentioned that IBM's Watson (shown in **Figure 2**) "... is now churning through case histories at Memorial Sloan-Kettering <Cancer Center>, learning to make diagnoses and treatment recommendations. This is one in a series of developments suggesting that technology may be about to disrupt health care in the same way it has disrupted so many other industries. Are doctors necessary? Just how far might the automation of medicine go?"

The first real world application for the Watson computer involves healthcare. Doctors have challenged Watson's and similar computer's clinical decisions as "only as good as the data sent to the computer." Clinical decision support systems do not replace doctors and their knowledge base, but are used to



FIGURE 1. Cover of *The Atlantic* magazine and robot doctor.

assist doctors in rapid disease diagnosis. These computers are certainly not 'robots' in any sense of the word, but people tend to place anything high tech like this in the robot category. When I was later sitting down and reading the article, a fellow traveler happened to see the article's title on the cover and began



FIGURE 2. IBM's Watson supercomputer.

to talk about robots. Not knowing that I was a robotics writer, he began to tell me about a knee replacement operation that was performed on him many years prior, and of all the surgical errors, staph infections, and negative after-effects that he endured. After finding out about my robotics background, he admitted that he felt that a robot should have done the operation instead of a human surgeon. I pointed out surgical robots are actually just extensions of a human surgeon and not an intelligent being.

Many People Feel Robots are Better

Hearing that comment started me thinking about the public's opinion of robots. Long before the word 'robot' came into existence, humans were trying to figure out what sort of mechanical device could take over work they just didn't like to do. Physically demanding jobs wore folks out. Jobs in hot places were quite unpleasant. Jobs in dangerous locations resulted in many injuries and deaths. As technology advanced, precision tasks like watch making and the assembly of complex devices took a lot of time and were taxing on the assembler. Certainly, a 'mechanical man' like the one in **Figure 3** could do the task better ... right?

Developing Robotics Applications at Rockwell

I would like to use some of my robotics background as a basis for "Why a robot?" In the early '80s, I was operating an antenna test facility for Rockwell's GPS satellite program when my chief engineer asked me to come to his office after he had seen an article I had written for *Popular Mechanics* on home-built robots — my number one hobby. It made the cover of the magazine and impressed him, so he asked me if I would like to help the company develop a robotics group to better understand how robots could be used in our many divisions. He wanted to send me to robotics labs at

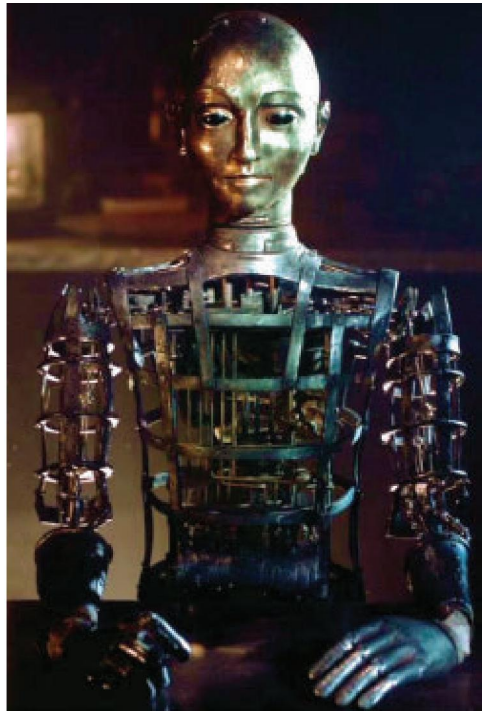


FIGURE 3. Generic 'mechanical man' to relieve us humans of drudgery.

companies and universities around the country and world to gather information and talk with key robotics developers.

I wondered what made me some sort of robotics expert, just because I had written an article about homemade robotics. The only aspect of robotics prowess in my background at that time was helping to form the Southern California Robotics Society (later called the Robotics Society of Southern California). There were members in that group who were far more knowledgeable about many aspects of robotics than I was. My chief engineer had a PhD in advanced physics and was a brilliant man, so I felt a bit honored that he had selected me to do this long-term study project. Being asked to do this research was tantamount of asking a kid if he wanted one of everything in Toys R Us. I took the project quite seriously. I traveled to Carnegie Mellon, MIT, Stanford and Georgia Tech Universities, and several other institutions of higher learning to talk with researchers and professors. I visited robot manufacturers, attended conferences, and delivered papers at RI/SME professional robotics

conferences held in either Detroit or in Chicago every other year. I got together with other Rockwell divisions and we formed a Robotics Task Group to determine how we could apply robotics technology to improve various processes and manufacturing lines within the company. Robotics was quite new and most robot applications were in large factory environments such as the automobile plants in Detroit. Robot implementation in the '70s and '80s was a lot like the early days of computers. Management felt if their competitor down the street had a computer, they'd better get one too.

So, Why a Robot?

There were assembly lines in our Troy, MI facility that made large truck axles and brake assemblies, and robotics was a key technology to improve those manufacturing lines. I worked in the aerospace division and we made a small number of very high-cost products such as multi-billion dollar space shuttles, multi-million dollar GPS satellites, rocket engines, and B-1 bombers. You just cannot make those products on an assembly line, as they are essentially hand-made. We did have a process in our Autonetics division that required a custom-designed and built robot to clean precision ball bearings for a missile navigation system in an ultra-clean environment. All of the ball bearings were identical in size and each of the cleaning operations were the same. One manufacturing process for the GPS satellites built in our Seal Beach, CA division (a drawing of one of the satellites is shown in **Figure 4**) was the precision assembly of the solar panels. I investigated the use of a robot to place each individual solar cell



FIGURE 4. GPS satellite — too difficult for a robot to assemble.



FIGURE 5. Robot spray painting a car.

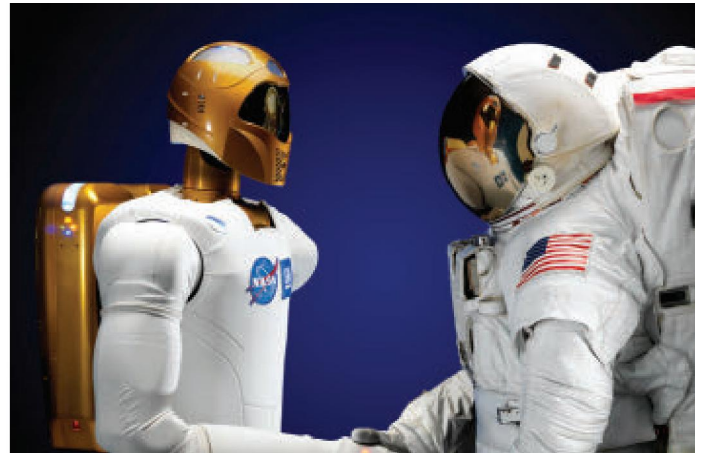


FIGURE 6. Robonaut 2 with human astronaut.

in the assemblies, but the idea was discarded. People were far better at this operation. After several years of research, those were the only aerospace applications I could identify.

I eventually described a few applications that we had in place and why they worked well to management. I also explained that a human is far more adept at certain tasks — especially where variability is necessary. If the required duties for a robot in an industrial application are the same every time, then a robotic installation might be the most economical solution. If careful hand manipulation of critical components is required, then humans are best suited for that.

Today's Robotic Applications

Today's intelligent vision systems coupled with an efficient multi-axis dexterous end-effector can detect different part orientations or defects,

and accept or reject a part as determined by the software. However, complete reliance on an advanced robotic system can lead to problems. Robotic automobile painting (Figure 5) is a good example. I remember reading about a car spray-painting robot system that was causing too much paint to be applied in one area. Excessive paint drips were forming, sliding, and drying in place. The operators didn't notice this problem until dozens of cars had passed through. It was a simple software error that was 'taught' but not checked thoroughly before starting.

Reasons to Use a Robot

When I researched reasons to use a robot, most were applicable to industrial applications, such as eliminating a human operator to save labor and reduce costs. Here's a list of some other reasons:

- Human handling is bad for the product (semiconductors, food, pharmaceuticals, etc.)
- Product handling is bad for humans (dangerous materials, heavy or hot materials, repetitive handling causing strains, etc.)
- Robots can increase the quality (painting, welding, deburring, repetitive or routing operations, assembly, etc.)
- Dangerous environments (radiation, space, extreme temperatures, long duration

spaceflight, hazardous military operations, etc.)

NASA Space Programs for Humans and Robots

There are many robot categories such as service robots, medical robots, military, and police robots that assist humans in ways other than factory situations, but balancing the *perceived* need versus the *real* need is sometimes blurry. NASA's manned space program is a good example. NASA has yet to create a robot astronaut that will completely dispense with humans in space. Yes, the NASA Robonauts (of which Robonaut 2 is shown in Figure 6) are amazing humanoid robots (developed specifically for space applications), but many space-borne tasks require a human at the site. Their recent success with Curiosity on Mars shows that robots (at least for now) are the best choice for distant space exploration.

Sending a robot into space or to a specific planet is relatively easy compared with sending a human. Curiosity (shown landing on Mars in Figure 7) is loaded with scientific instruments, is RTG nuclear powered, and can traverse the Martian surface for many miles, continually sending valuable visual and instrumentation data back to Earth. To send a couple of 180 pound humans to the same location would require a much larger launch system to carry the many tons of food, water, and oxygen required to

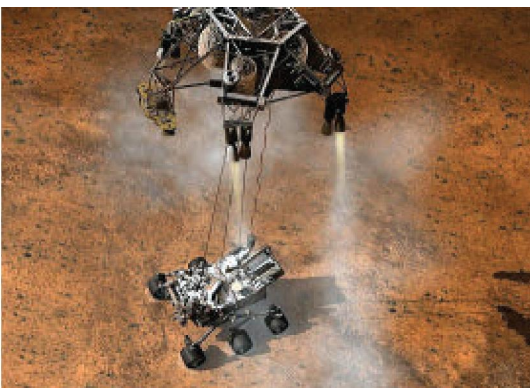


FIGURE 7. Mars rover Curiosity landing.



FIGURE 8. Space Station's CanadArm2 positions an astronaut.



FIGURE 9. Rethink Robotics' Baxter.

keep the humans alive — not only for the outbound trip and the time on the planet's surface, but for the return trip, as well.

Of course, electrical power generation equipment, scientific analysis tools, space suits, radiation shielding, and a habitat large enough for two people to live, eat, and do work in is also required. Another major item to consider is the space 'vehicle' to launch them from the surface of the planet back to Earth.

Although the surface gravity on Mars is only one-third that of Earth, the vehicle would have to be quite a bit larger than the Apollo lunar Earth-return vehicles to carry the astronauts and their life support supplies and food. So, with these two scenarios in mind, which would you choose: people or a robot?

Other Applications for Robot Spacecraft

It's a bit obvious that I appreciate the technology involved in the

development of space robotics considering that I spent over a decade working in various NASA programs. Robot spacecraft can actually be two different things.

When we generally think of robots in space, we envision planetary rovers like Spirit, Opportunity, and Curiosity, plus the deep space craft Voyager. The other category includes robots such as the CanadArm, Robonaut, and robotic devices to service manned and unmanned spacecraft.

It is also obvious that deep space exploration must use robots, as humans cannot withstand multi-year, one-way space trips. The service category of space robots is sometimes a gray area in that humans can do many of the tasks given over to these robots.

The Space Station's CanadArm2 shown in **Figure 8** might be the only exception since it is used to maneuver very large multi-ton payloads, as well as individual astronauts.

Can Robots Work Side by Side with Humans?

Rodney Brooks, co-founder of iRobot and MIT professor, is CEO of Rethink Robotics. His company's product, Baxter, does not resemble any other industrial robot ever produced. The gray and bright red two-armed robot with a friendly face displayed upon its LCD screen is Brooks' latest venture to change how industry perceives robots. Shown in **Figure 9**, Baxter is placing newly machined gears into a shipping box. What makes Baxter different is it is designed to work alongside humans.

Baxter uses Willow Garage's open source Robot Operating System (ROS) language and is trained for each new job by a factory person showing the robot how to perform the task. A recent article in *Forbes Magazine* covered Brook's endeavor. "Baxter is also a complete system that can be unpackaged and working in less than an hour, and be trained by

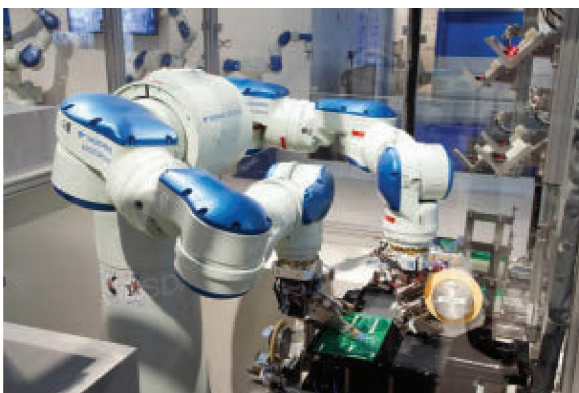
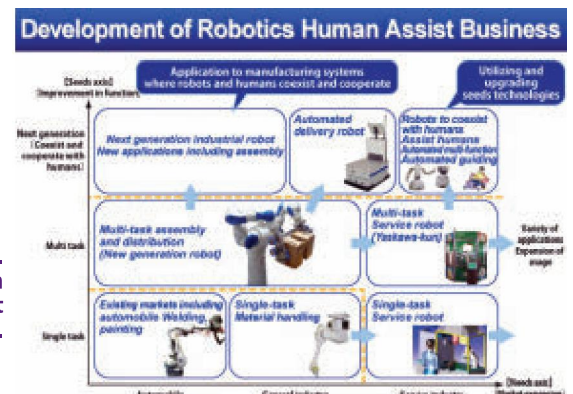


FIGURE 10. Yaskawa dual-arm robot.

FIGURE 11. Yaskawa Human Assist robot strategy.



nontechnical personnel. Employees can train Baxter to do a new task just by showing him what to do — no software programming is needed. So now, humans get to supervise robots instead of doing mundane tasks; people working alongside robots. Rethink focused on the simplicity of integrating Baxter into a manufacturing environment so a company doesn't have to reconfigure their manufacturing lines."

"Over the next 20 years, no one is going to mistake a robot for a person, but nevertheless, we will interact and collaborate with robots and they will become as commonplace in our lives as turning to a search engine is today," said Brooks in the article. "Robots will become cheaper and more adaptive to their surroundings.

No one will find it surprising they can train a robot to do a new task for them in just a few minutes," added Brooks. (Go to rethinkrobotics.com for more information about the company and Baxter.)

Yaskawa Motoman's Robot Plays Blackjack

At the recent Automate 2013 show of automation and robotics, Yaskawa's SDA10F dual-armed robot shown in **Figure 10** drew large crowds to watch the robot deal cards, as well as reading them. Certainly, Yaskawa does not intend to displace the world's blackjack dealers with robots, but wanted to showcase this special type of robot that — just like Baxter — can operate alongside humans. It was the

level of dexterity that the robot exhibited, as well as the 640x480 pixel VGA CCD camera vision system that impressed the crowds at the exposition. The arms can handle 10 KG or 22 pounds each. The seven DOF arms can rotate at 180° per second. The company used this particular

type of demonstration as a crowd-gathering technique at various trade

shows, and it worked.

Yaskawa's business goals have expanded a bit beyond the typical industrial robots, of which the company has more than a quarter million installed around the world. "Our aim in the robotics human assist business is to focus on our core business of industrial robots. At the same time, we also intend to create a market for robots that are easier to use and that function in domains more closely involved with people."

The company is planning a large expansion of their market into the service robot category and intends to use their industrial robot experience to produce these types of robots.

Yaskawa developed the chart in **Figure 11** to illustrate how some of their industrial robot lines have evolved into new applications; the illustration is very useful to anybody studying human assist robot technology. Go to yaskawa.com for more information about the dual-arm robot and their other robot lines.

Final Thoughts

The use of robots in our society has greatly improved efficiency, safety, productivity, product quality and has even saved many lives. Robots have not displaced workers but have

augmented their capabilities many times over. The unmanned drones in war zones have saved many would-be pilots lives. The secret DOD/Boeing X-37B unmanned robot space plane shown in **Figures 12A and 12B** has certain governments (not friendly to the US) nervous as to its exact purpose. Adam Harvey has a new line of 'stealth wear,' also called 'Anti-Drone Wear' shown in **Figure 13** to allow people to hide from drones.

Much smaller than the Space Shuttle, drones are the wave of the future.

Robots are definitely here to stay. **SV**



FIGURES 12A and 12B. Boeing X-37B space-plane.

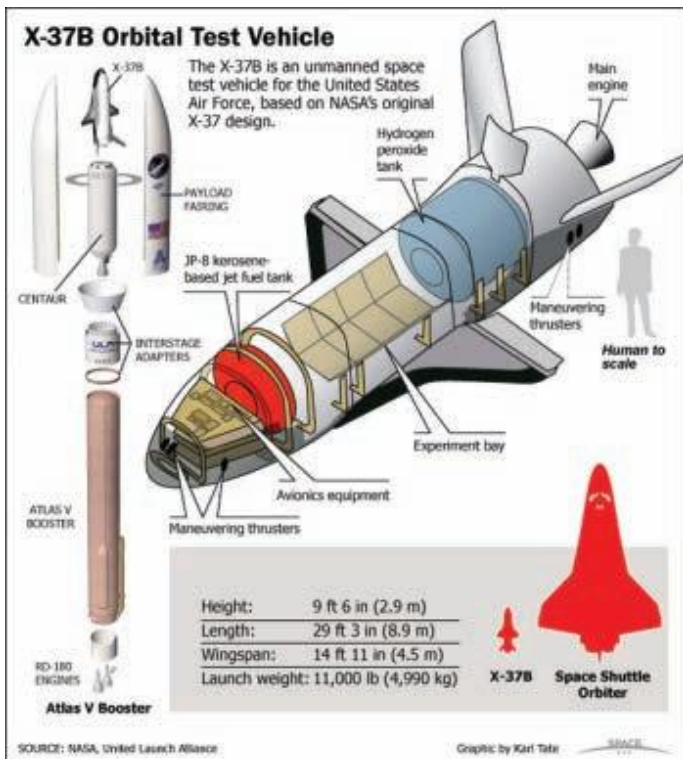
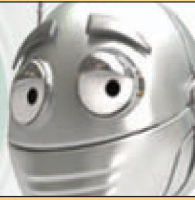


FIGURE 13. Anti-drone stealth wear burqa.

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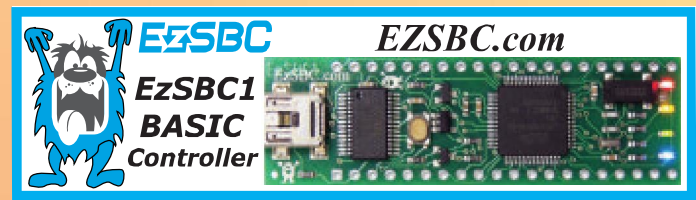
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No load current	A	0.61	1.06	1.18
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Continuous torque	Nm	5.596	21.142	39.131
Continuous current	A	1.989	5.930	9.505
Maximum output power	W	23.64	144.58	262.66
Resolution	Step/turn	304,000	502,000	502,000
Gear ratio	-	304	502	502
Backlash	arcmin	3.5	3.5	3.8
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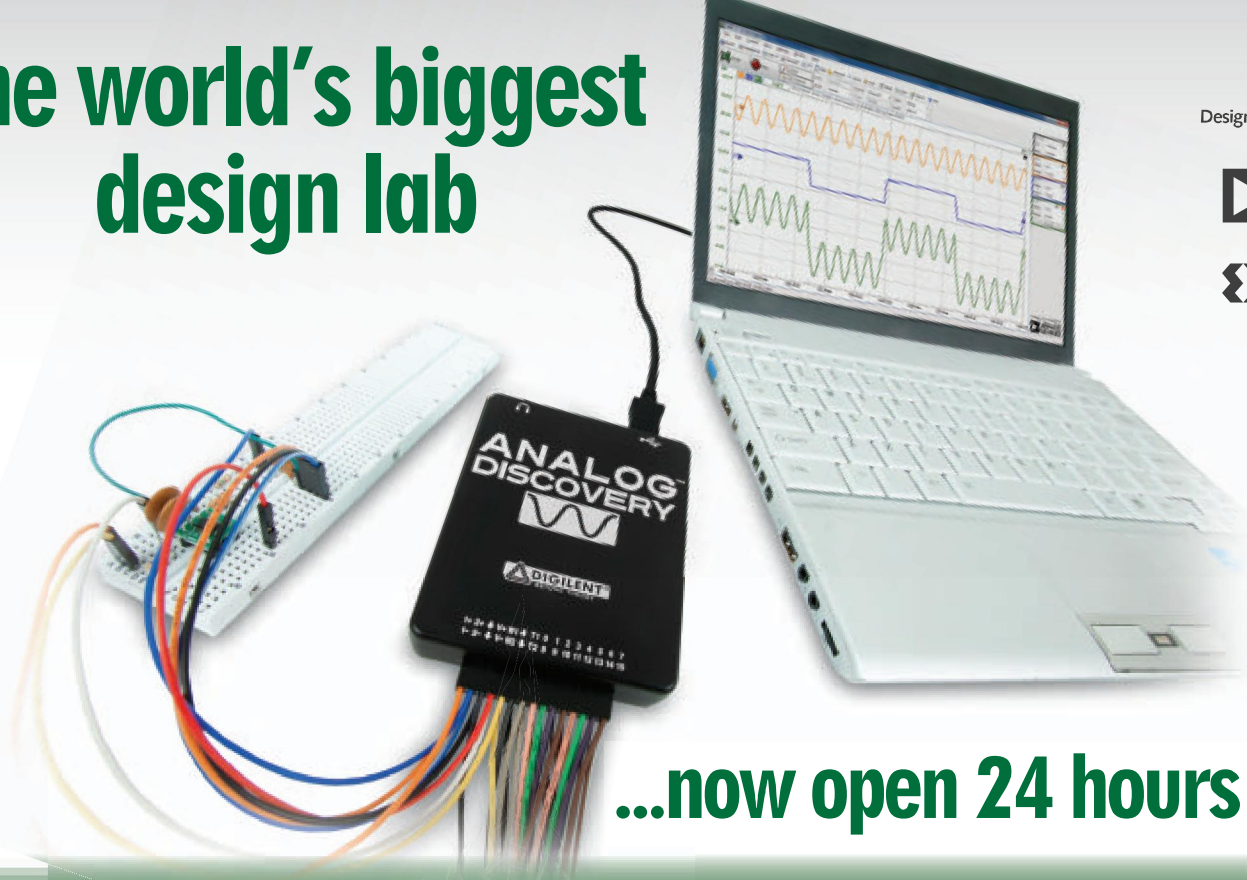


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